The role of attention in learning for pupils with and without autism

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Thesis abstract

In this thesis, an in-depth investigation into the relationship between attention abilities and learning in primary school aged children with and without an Autism Spectrum Disorder (ASD) was conducted. This investigation began using standardised assessments of attention and academic achievement to enable the measurement of abilities while taking age into account (Study 1). Divided attention was related to reading and maths for autistic pupils and played a role in defining different profiles of achievement. Subgroups of children with better or poorer divided attention showed different within-domain strengths and in reading and maths. Further analysis revealed that similar profiles existed transdiagnostically, highlighting the importance of considering ASD alongside TD children, as opposed to between groups.

To consider the real-world manifestation of these relationships, Study 2 used measures that represented classroom-based attention and learning. This included eye tracking as a real-time attention measure, videos of short lessons to stimulate learning, and a computer-based measure of attention abilities. Sustained attention was transdiagnostically important for attending to relevant information during a lesson (i.e. looking at the teacher), and for learning from that lesson. Autistic children benefited from allocating visual attention to the teacher during lessons, but this was not true for TD children. Several autistic children could not successfully complete the eye-tracking task, and an initial investigation suggested that this was due to differences in cognitive ability and behaviour. This indicated the importance of considering within group heterogeneity, as well as other factors at play.

The final two studies therefore aimed to consider the role of other factors impacting on the relationship between attention and learning in ASD, beginning with a qualitative exploration in a real-world context (Study 3). Semi-structured interviews with teachers revealed the complexity of this relationship, with a particular focus on the roles of anxiety and sensory processing difficulties. Study 4 investigated these factors quantitatively using parent-report measures of anxiety and sensory processing, which ultimately reinforced the findings of Study 3. In ASD, increased levels of anxiety were related to poorer divided attention and reading achievement, suggesting both anxiety and attention play an important role for children while learning in the classroom. Sensory processing symptoms played an indirect role, as they were related to anxiety in ASD, but not attention or achievement.

Taken together, this mixed methods thesis provided a rich and comprehensive understanding of the relationship between attention and learning in ASD. Throughout the thesis, the theoretical and practical implications of these findings are discussed, in addition to suggestions for accounting for heterogeneity in both attention and learning in this group.

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Declaration

Content from Chapter Three has been submitted to a special issue of *Research in Developmental Disabilities*, in which Professor Deborah Riby and Dr Mary Hanley are also listed as authors. All three parties were involved in conception and design of the study. Emily McDougal performed the statistical analysis and drafted the manuscript. Deborah Riby and Mary Hanley contributed to drafting the manuscript.

At the time of submission, no other content from this thesis has been published, nor is it under review for publication.

Statement of copyright

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Chapter One: General introduction

Utilising a mixed methods approach, the general aim of this research was to undertake an in-depth investigation into the relationship between attention abilities and learning in primary school aged children with and without an Autism Spectrum Disorder (ASD). Despite this area receiving interest in relation to typical development, to date the role of attentional atypicalities in learning in ASD has been overlooked. The current chapter will provide an introduction to ASD, attention theory more generally, but also its relevance in typical development and ASD. Following this will be a brief introduction to the role of attention in learning, preceding a detailed literature review in Chapter Two of the relationship between attention and academic achievement for children with and without ASD.

1.1 Autism Spectrum Disorders

Autism Spectrum Disorders (ASD) is a classification of neurodevelopmental disorders characterised by difficulties in social communication and interaction, and restricted and repetitive behaviours. According to the Diagnostic and Statistical Manual, fifth edition criteria (DSM-5; APA, 2013), individuals diagnosed with ASD could fall anywhere along a spectrum of autistic functioning, but at the core of their diagnosis is this dyad of "impairments". The atypicalities of social functioning for individuals diagnosed with ASD can include difficulties with expressive and receptive verbal and non-verbal communication, social approach and reciprocity, and the development and maintenance of relationships (Chevallier et al., 2012). Restricted and repetitive behaviours refer to an inflexibility of behaviour, including repetitive motor movements, insistence on sameness, and restricted interests (Leekham, Prior & Uljarevic, 2011). Now also included as a subcategory within this characterisation of behaviour are atypicalities in sensory processing behaviours, which refer to hyper- or hyposensitivity to sensory stimuli, and the behaviours associated with these sensory experiences (Dunn, 1997). Importantly, ASD is considered to be a highly heterogeneous disorder (Charman et al., 2011; Geschwind & Levitt, 2007), particularly since the re-classification from DSM-IV (DSM-IV-TR, published in 2000) to DSM-5 (published in 2013) to no longer include autistic disorder, Asperger's disorder or pervasive developmental disorder not otherwise specified (PDD-NOS). While this poses significant challenges to research, recognising and studying this heterogeneity may provide significant contributions to our understanding of the disorder as a whole (Georgiades, Szatmari, & Boyle, 2013).

Throughout the history of autism research, many theories of the disorder have been proposed; the aim of most has been to provide a unitary explanation of autism that can explain all aspects of the disorder. These traditional models are well established and supported by extensive research, however they share the limitation of being unable to account for every feature of ASD. For example, Social Motivation Theory (Chevallier et al., 2012; Clements et al., 2018) explains the social challenges that autistic individuals experience, however it is not able to explain all of the cognitive atypicalities that exist. Conversely, cognitive theories such as Executive Dysfunction (Pennington & Ozonoff, 1996; Hill, 2004) and Weak Central Coherence (Frith, 1989) can account for some of the cognitive atypicalities but not the social aspect of autism. As no theories to date can offer comprehensive models of the autism phenotype, modern research has focused on explanations based on a fractionation of the ASD features (Happé, Ronald & Plomin, 2006), particularly between social and non-social symptoms. This theoretical perspective is grounded in the notion that ASD is a result of a combination of separable but related causes at the biological and/or behavioural level. As such, it is important to recognise this when explaining cognition or behaviour with particular models, acknowledging that the model may explain part but not the whole of ASD. An extensive review of all theories of autism is not practical or relevant within the scope of this thesis, however a number of papers exist for a more thorough review of the wider autism theories (Chevallier et al., 2012; Clements et al., 2018; Frith, 1989; Happé et al., 2006; Happé & Booth, 2008; Hill, 2004; Levy, 2007; Pellicano & Burr, 2012; Pennington & Ozonoff, 1996; Ranjedran & Mitchell, 2007). As this thesis will focus on understanding attention in autism, and attention is a gateway to higher-order cognitive processes (Diamond, 2013; Fougnie, 2008; Posner & DiGirolamo, 1998; Theeuwes, 1991), the theory most relevant to this aspect of the disorder, executive dysfunction, will be discussed.

1.1.2 Executive dysfunction as a theory of Autism

Executive function encompasses a range of cognitive components that are related to goal-directed behaviour, including planning, self-regulation, inhibition and working memory. In order to understand the relevance of executive function in autism, the core components will be defined. Working memory is necessary for the execution of cognitive tasks in which information must be held in mind (Baddeley & Hitch, 1974), for example, following directions or conducting mental arithmetic. Working memory has therefore unsurprisingly been linked to cognitive development and learning (Cowan, 2014). Inhibition, or inhibitory control, is the ability to control a variety of human functions such as behaviour, attention, or emotions (Diamond, 2013). A lack of inhibition is therefore related to impulsive behaviour or actions (Bari & Robbinds, 2013). These components also feed into what are considered to be higher-order executive functions, such as reasoning, problem-solving and planning (Diamond, 2013). Difficulties in any of these areas can therefore have a substantial impact on a variety of outcomes, most notably for the current thesis upon educational outcome (Gordon et al., 2018).

The theory of executive dysfunction (ED; Pennington & Ozonoff, 1996; Hill, 2004) posits that atypicalities in executive function can explain some of the cognitive and behavioural manifestations of autism. In particular, links have been made between cognitive flexibility and restricted and repetitive behaviours (e.g. Miller et al., 2015).

Many accounts of atypicalities in executive function for autistic individuals have been reported (see Hill, 2004 for a review), particularly mental flexibility, planning and attention (Ozonoff, 1995; Ozonoff, Pennington & Rogers, 1991; Russell, 1997). Hughes, Russell and Robbins (1994) used a variation of the 'Tower of Hanoi' task to measure planning ability with 7 to 18-year-olds with autism (N = 35). Both groups performed significantly worse than chronological age-matched and mental age-matched groups; fewer autistic participants successfully completed the task, and those who did required more moves to do so and made more errors. These findings suggested atypicalities in planning for autistic individuals. Importantly, however, when participants completed different stages of difficulty with the task (i.e. easier stages required fewer moves to solve the puzzle), differences between groups only existed for the more difficult puzzles. This suggests that more complex planning may be a difficulty that some individuals with autism face, which the authors relate to day-to-day planning that may impact on daily life, but that more simple forms of planning may not be problematic.

Cognitive flexibility has also been found to be atypical in autism, mostly evidenced by performance on the Wisconsin Card Sorting Task (WCST; Heaton et al., 1993). This task requires participants to sort cards based on colour, shape or number, without being given explicit instructions, meaning that the rule must be learned using only feedback on whether or not the choice was correct. Moreover, the rule changes several times throughout the task, meaning participants must be able to adapt their strategy appropriately. Shu, Lung, Tien and Chen (2001) found that children with autism (N = 26, aged 6 to 12 years) performed worse on the task than IQ-matched controls; specifically, they made more errors and required more trials to complete the task. This suggests that autistic individuals may have difficulties with cognitive flexibility. However, Kaland, Smith and Mortensen (2008) found that differences in performance between individuals (Mean age = 15.4) with Asperger's or "high-functioning" autism (N = 13) and typically developing (TD) controls were not significant, apart from in their ability to maintain the sorting principle. The authors argue that this is an indication of atypical sustained attention, as opposed to mental flexibility, in autistic individuals with higher cognitive ability. It is, however, important to note that this was a very small sample that also likely represented a sub-group of autistic children different to the sample in Shu et al.'s (2001) study. Indeed, in Shu et al. (2001) the IQ of the autism sample ranged from 65 to 112 (M =

80), potentially representing some children with intellectual disability, whereas in Kaland et al. (2008) the sample represented a higher functioning group whose IQ ranged from 94 to 125 (M = 109). It may therefore be the case that this heterogeneity can explain these different patterns of ability, specifically that autistic children with higher IQ do not have difficulties with mental flexibility, but, according to Kaland et al. (2008), rather their difficulties are with attention. Indeed, attentional atypicalities in autism have been reported consistently (e.g. Burack, 1994; Dawson et al., 1998; Mayes & Calhoun, 2007; Renner, Glofer Klinger & Klinger, 2006), which will be discussed later in this chapter.

Although the literature described above demonstrates that atypicalities of executive function exist in ASD, not all studies agree, indicating within-syndrome heterogeneity and suggesting that the theory of executive dysfunction may not be supported in every individual with ASD. As previously mentioned, attention and executive function are inherently connected (Diamond, 2013; Fougnie, 2008; Posner & DiGirolamo, 1998; Theeuwes, 1991), therefore understanding the atypicalities of attention in autism may also shed light on the wider autism phenotype. Indeed, the second core focus of this thesis is attention, therefore the following section provides a brief introduction to attention more broadly.

1.2 Attention

Attention is a vital cognitive process as it determines what information from the environment is selected, and as such, is a gateway to many higher order processes such as perception, memory and learning. James (1890) famously described attention as "the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought, localization, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others, and is a condition which has a real opposite in the confused, dazed, scatter brained state which in French is called distraction" (p. 404). Theories of attention provide a framework for understanding the structure of attentional processes, how they interact with one another, development across the lifespan, and the impact upon dependent functions.

The notion that attention is comprised of three separable but related processes is well established and supported by the extant literature (for a review see Petersen & Posner, 2012), these being alerting, orienting and executive attention (Posner & Petersen, 1990). Alerting refers to the ability to sustain attention over time and remain vigilant while doing so, and therefore encompasses both vigilance and sustained attention. Orienting is the ability to select appropriate information amongst distractors, also known as selective attention, and encompasses the ability to filter out irrelevant information in addition to knowing what to attend to. Executive attention refers to the ability to control, shift, or divide attention while ignoring conflicting information. There are similarities between selective and executive attention in that they both require ignoring irrelevant information. In differentiating these processes, Lavie, Hirst, de Fockert, and Viding (2004) explain that selective attention is a passive mechanism that selects only relevant stimuli (amongst distractors) under situations of high perceptual load. By comparison, executive attention rejects irrelevant distractors in situations of low perceptual load and relies on higher cognitive functions such as working memory. Research has provided evidence for the existence of neural networks for each attentional process (e.g. Fan, McCandliss, Fossella, Flombaum & Posner, 2005), and that although these networks are independent, they do interact (Callejas, Lupianez & Tudela, 2004). It is not relevant to go into depth in relation to the neural underpinnings of attention and attentional mechanisms here, as the current thesis focuses on cognition and behaviour as opposed to neuroscience. However, Petersen and Posner (2012) published a review of this literature, which can be referred to for an up to date overview of this topic.

Although theories of attention in adulthood are important for characterising this domain-general aspect of cognition at an end state, to fully understand attention it is vital to identify its developmental progression. The following section will therefore focus on attention in typical development.

1.2.1 Attention in typical development

Understanding the developmental trajectories of sustained, selective and executive attention is important; although attention is a domain-general ability, it is comprised of distinct components, each of which may develop at different rates and mature at different timepoints. When examining attention in children, it is therefore important to be aware of what level of performance to expect for each attentional component within and between age groups. A body of literature has attempted to map the developmental trajectories of sustained, selective and executive attention from early childhood to adolescence (e.g. Lewis, Reeve & Johnson, 2018; Pozuelos, Paz-Alonso, Castillo, Fuentes, & Rueda, 2014; Steele, Karmiloff-Smith, Cornish & Scerif, 2012). Although there is some consensus, the findings are somewhat mixed. The following section will briefly review this literature, including a short description of the methods typically used to measure each attentional component.

Sustained attention is typically measured using continuous performance tasks (CPT; Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956) in which the child must remain alert for long periods of time while waiting to respond to specified targets. Studies have successfully administered the CPT with children as young as 2 years (e.g. Akshoomoff, 2002). In general, research investigating sustained attention agrees that its development follows a linear trajectory in early to middle childhood. Evidence of this trajectory is present early in childhood, with CPT performance improving from 3 to 6 years of age (Steele et al., 2012), and between groups of 3 to 4-year-olds and 5 to 6-year-olds (Berwid et al., 2015). Research has shown that this linear trajectory continues into middle childhood, with evidence of improvements over time for 6 to 11-year-olds (Lewis, Reeve & Johnson, 2018). Some evidence suggests that sustained attention continues to improve into adulthood (Rueda et al., 2004), while others have found that it matures around late childhood. For example, Lin, Hsio, and Chen (1999) found evidence of a quadratic relationship between CPT performance and age in 6 to 15-year-olds, in that it improved rapidly in early childhood but levelled off in late childhood and into adolescence. These differences in findings may be attributed to sample size. While the conclusions of Lin and colleagues regarding the developmental trajectory of sustained attention were based on data from a large sample of 341 children, Rueda and colleagues used much smaller sized samples. Furthermore, the latter compared performance between 10-year-olds and adults, whereas the former study examined the abilities of children across a wide age range. Based on these findings it can be assumed that sustained attention develops throughout early childhood, particularly during the primary school years, but becomes adult-like in late childhood.

Selective attention is typically measured in children with the use of visual search tasks, which aim to measure an individual's ability to select relevant stimuli while ignoring distracter items, and can be adapted for even very young children (Scerif, Cornish, Wilding, Driver, & Karmiloff-Smith, 2004). Participants are presented with a set of images on a page or computer screen, and are asked to select the target images amongst distractor items. Typically, reaction time and accuracy data are used as measures of selective attention. Selective attention also appears to develop linearly in early childhood, but research suggests that it matures earlier than sustained attention. Steele et al. (2012) found that visual search task performance improved between 3 and 6 years of age, suggesting that selective attention developed linearly between these ages, similarly to sustained attention. The literature relating to selective attention in middle childhood is somewhat mixed. Lewis et al. (2018) examined selective attention in 6 to 11-year-olds, finding no evidence of improvement longitudinally or between age groups. Similarly, Rueda et al. (2004) found no change in ability from 6 to 9 years of age, or from 10 years to adulthood. Comparatively, Pozuelos et al. (2014) found that selective attention improved from 6 to 8 years of age, but that development was stable after age 8 years. These studies concur that selective attention does not improve after age 8, but there is some disagreement regarding the point at which it matures, which based on these findings appears to be between 6 and 8 years of age. One explanation for this disparity is the way in which children were grouped may have impacted on group comparisons. For example, Lewis and colleagues grouped children into three groups; 6 to 7-year-olds, 8 to 9-year-olds and 10 to 11-year-olds. By comparison, Pozuelos and colleagues initially compared children aged 6, 7, 8, 9, 10, 11 and 12 years to one another, then clustered age groups that did not differ from one another to create meaningful age groups. This method will have allowed more meaningful group differences to emerge, as opposed to arbitrary age groups as in Lewis et al. (2018).

Tasks that measure executive attention generally require the resolution of conflict, otherwise known as spatial conflict tasks. For example, flanker tasks require participants to make decisions about the status of arrows and digits, while ignoring congruent and incongruent distractor items. Mean reaction time for incongruent trials is typically used as the measure of executive attention, but this varies between studies. Steele, Karmiloff-Smith, Cornish and Scerif (2012) successfully measured executive attention in 3 to 6-year-olds using a computer based spatial conflict task. All children were more accurate and quicker at responding to congruent compared to incongruent targets, demonstrating the early emergence of this attentional process. The authors do, however, highlight the importance of recognising the specific demands of a particular task, as the type of executive attention recruited may vary between tasks (e.g. shifting, inhibition, dividing attention). This is an issue that will be referred to throughout the thesis.

The literature regarding the development of executive attention is less consistent than accounts of sustained and selective attention. Steele et al. (2012) found that there was no difference in executive attention from 3 to 6 years of age, which may suggest either early emergence of this ability that was not captured in their sample, or alternatively, that it develops later in childhood. Lewis et al. (2018) found that there were improvements in executive attention over time in 6 to 7-year-olds, but that performance did not improve in 8 to 11-year-olds. This supported findings from Rueda et al. (2004), who also found that executive attention development appeared to stabilise around 7 years of age, however, Pozuelos et al. (2014) found that executive attention did improve from 7 to 12 years. These differences could be attributed to the difference in tasks between studies; although all three of these studies used the Attention Network Task (ANT; Fan, McCandliss, Sommer, Raz, & Posner, 2002), a computer-based measure of attention, different versions of the task were used. This task is particularly relevant for the current thesis, used in Chapter Four, and a detailed description of the task and the implications of using different versions will be included in the appropriate chapter. That said, it is appropriate here to recognise the sensitivity of tasks, and the impact that small adjustments may have upon results. The developmental trajectory of executive attention is therefore unclear, but what this literature does demonstrate is the existence of this component in children.

Although there is still some debate regarding the pathway of development that each component of attention follows, what these studies show is that each component has a distinct developmental trajectory, supporting the multi-component theory of attention. Critically, this highlights the importance of measuring each component independently to effectively examine attention in developmental groups. Although attention is a domain-general process, if each component develops differently it is entirely possible that different profiles of attentional strengths and weaknesses impact on domain-specific processes in different ways. Obtaining a detailed profile of attention in different developmental groups (i.e. typical and atypical development) is the vital first step for understanding how attention may influence developmental outcome. The next section will therefore review the literature relating to attention in autism.

1.2.2 Attention in autism

Broadly speaking, attention atypicalities in ASD are well-documented (Ames & Fletcher-Watson, 2010), and have been investigated in reference to sustained, selective and executive attention, which has furthered the understanding of how attention in autism may be different compared to neurotypical individuals.

Sustained attention has generally been found to be typical for individuals with autism (e.g. Garretson, Fein & Waterhouse, 1990; Keehn, Lincoln, Muller & Townsend, 2010; May, Rinehart, Wilding & Cornish, 2013, 2015; Pascualvaca, Fantie, Popageorgiou & Mirsky, 1998). For example, Garretson et al. (1990) administered a CPT with 6 to 12-year-olds with autism and mental age matched controls, finding that the groups did not significantly differ in terms of accuracy or response time, suggesting that sustained attention in autism is comparable to typical development. Other studies (see above) have since reported similar findings. Fan (2013), however, argues that when considering the two types of alerting functions separately, tonic and phasic alertness, by analysing past data, atypicalities emerge. He adds to this argument by highlighting studies that have found evidence for anatomical abnormalities in the brain in autism that have been associated with alerting (e.g. Courchesne et al., 1994; Hashimoto et al., 1995). The data Fan referred to were, however, not reported or cited, and the links between alerting and cerebellum and/or brainstem abnormalities are somewhat speculative. The majority of research examining sustained attention does find its performance to be comparable between autistic and TD individuals.

Atypicalities in selective attention have been found in autism, with even very young children showing difficulty with visually orienting to both social and non-social stimuli (Dawson, Meltzoff, Osterling, Rinaldi & Brown, 1998; Swettenham et al., 1998). There is evidence to suggest that these orienting atypicalities continue into later childhood and beyond (e.g. Burack, 1994; Keehn et al., 2010; Mutreja, Craig & O'Boyle, 2015; Renner, Grofer Klinger & Klinger, 2006). For example, Keehn et al. (2010) administered the adult ANT with 20 autistic and TD 8 to 19-year-olds matched on age and non-verbal IQ to investigate the attentional profiles of autism in comparison to typical development. They found that individuals with autism had poorer orienting efficiency compared to TD participants, whereas alerting and executive efficiency was comparable between groups. Renner et al. (2006) investigated the atypicalities of orienting in autism in more detail, looking at both exogenous (i.e. automatic) and endogenous (i.e. controlled) orienting abilities. They used a central cueing paradigm in 7 to 17-year-olds to examine differences in orienting based on peripheral (automatic orienting) and central (controlled orienting) cues, and compared performance against a TD group matched on age and verbal ability. They found that while endogenous orienting in ASD was comparable to TD children, exogenous orienting was poorer, suggesting atypicalities in the automatic orienting of attention. This may explain the finding that individuals with autism generally perform above average on visual search tasks (e.g. Joseph, Keehn, Connolly, Wolfe & Horowitz, 2009), despite atypicalities in attention orienting. It may be the case that when an individual knows what information they are looking for, they can find this amongst distractors, while they have difficulty orienting their attention when the appropriate target is not explicit. According to Kirk, Gray, Riby, Taffe and Cornish (2016), however, it may only be autistic individuals with average or above average IQ who demonstrate this enhanced visual search performance.

While studies of selective attention in autism generally focus on orienting of visual attention, some research has found that the atypicalities of orienting attention may also be applicable to the auditory domain. Teder-Sälejärvi, Pierce, Courchesne and Hillyard (2005) examined this in adults with and without autism, who were matched for age, sex and handedness, by asking them to discriminate between sounds from speakers in several different locations. Participants were told to attend to a particular sound (i.e. higher pitched noise bursts) at a particular location (i.e. central or right peripheral), and press a button when this occurred, while ignoring continuous auditory distractors from other speakers. They found that autistic individuals performed significantly worse than controls on this task, in that they were both slower to respond and less accurate. This suggests that the selective attention deficits in autism are not specific to the visual domain, but also apply to auditory stimuli. This finding is important, as although selective attention is most commonly measured in the visual domain, children receive information through both sight and sound. The notion that selective attention is atypical in both these sensory domains is pertinent for understanding the attentional profile of autistic children, and is highly relevant when considering the role of attention in learning, which can be delivered both visually and orally. Autistic individuals have been shown to prefer to look at non-social over social stimuli (Klin, Jones, Schultz, Volkmar & Cohen, 2002; Hanley et al., 2013, 2014; Riby & Hancock, 2008), demonstrating that these atypicalities of selective attention also impact on the social domain in autism.

Although the literature in relation to executive function in autism is vast, executive attention specifically has generally been overlooked. Furthermore, the literature surrounding executive attention in ASD is somewhat limited compared to the other components of attention, however, some research has found evidence for atypicalities in this domain (e.g. Casey, Gordon, Mannheim & Rumsey, 1993; Mutreja, Craig & O'Boyle, 2015), although others have not found evidence of this (e.g. Hames et al., 2018; Keehn et al., 2010; May et al., 2013). Mutreja et al. (2015) compared ANT performance between 5 to 11-year-olds who had autism (N = 14) or were typically developing (N = 51). Groups were matched on age and non-verbal IQ. They found that although autistic children did not differ compared to TD children in terms of reaction time when responding, they were less accurate when responding during incongruent trials. By comparison, Hames et al. (2018) found that adolescents with autism did not differ in the efficiency of their executive attention network compared to TD controls. Keehn et al. (2010) report similar findings when comparing 8 to 19-year-old TD and ASD groups. It is possible that these differences between studies are related to differences in age, as the children reported by Mutreja and colleagues were much younger; it is possible that this task was too easy for the older children. Alternatively, it may be the case that the developmental trajectory of executive attention is different in ASD, in that the ability matures later compared to typical development. It is difficult to draw any solid conclusions from this literature, considering the differences between studies, however, considering the vast literature evidencing atypicalities in executive function, it seems appropriate to assume that these atypicalities also apply to executive attention.

There are two important observations to be made about the attention in autism literature. First, the age ranges of children recruited to these studies are often wide, which poses an issue relating to the trajectories of attention, as described above in relation to executive attention. As the TD literature provides evidence for distinct developmental trajectories for sustained, selective and executive attention, it follows that this should also be recognised in studies of ASD. It is therefore important to recognise that age may play an important role in attention, and take this into account when conducting research. Using standardised assessments that take age into account, as well as including age within analyses, can help to address this. The second observation about studying attention in autism is the range of tasks used to measure attention. This will be discussed in more detail in the following chapter, however, it is important to recognise that although multiple tasks may aim to tap the same process, the demands of the task upon other aspects of cognition may differ (e.g. verbal ability, general intelligence). Both of these issues are of particular importance when considering the relationship between attention and other outcomes.

1.3 Relationship between attention and learning

Central to this thesis is the relationship between attention and learning. Understanding how to support children and young people in achieving their full potential at school is a vital part of education. To do this, the factors that can influence learning must first be understood. This topic has been widely researched for typically developing (TD) individuals, with intelligence (Neisser et al., 1996), working memory capacity (Gathercole et al., 2004), and self-discipline (Wolfe & Johnson, 1995), amongst many other factors, being related to academic achievement. Research in this area has, however, been neglected for children with ASD. Academic outcomes for individuals with ASD vary a great deal (Keen, Webster & Ridley, 2016), but are generally reported as being poorer than for TD children, therefore it is arguably even more important that focus is given to improving their potential outcomes.

The ability to focus attention on task-relevant information is crucial for learning (e.g. Erickson, Thiessen, Godwin, Dickerson & Fisher, 2015; Oakes, Kannas & Shaddy, 2002), and according to Carroll's "time on task" hypothesis, the more time spent on task, the better the learning outcome (Carroll, 1963). In the context of academic achievement, this implies that if children cannot concentrate during lessons, their academic outcomes may be limited. The literature regarding the relationship between attention and academic achievement in both TD and ASD children will be reviewed in detail in Chapter Two, however, a brief overview of the key studies relating attention and learning in the context of classroom-based education will be provided here.

Studies have found that in TD children, the classroom environment can impact on learning (Barrett, Davies, Zhang & Barrett, 2015), and that this may be due to visual displays distracting attention. Fisher, Godwin and Seltman (2014) investigated this further by conducting an experiment in which they manipulated the visual displays in a classroom and measured the effect upon attention and learning in TD children. Twenty-four kindergarten children (mean age 5.7 years) took part in six 5- to 7-minute science lessons within a laboratory classroom, and after each lesson, learning was measured using worksheets. The walls of the classroom were either bare or decorated with visual displays typically found in a classroom, and these conditions alternated between lessons. The purpose of this was to evaluate whether the level of visual distraction impacted upon the way attention was directed during lessons, as well as if attention behaviours of the children (i.e. on-task or off-task attention) impacted upon learning outcomes. They found that children spent more time off-task and achieved poorer learning outcomes in the decorated condition, suggesting that their visual distraction from the lesson impacted negatively on how much they learned during the lesson. Although this experiment had high ecological value, looking behaviours were coded by researchers to determine on-task and off-task behaviour, which is an indirect measure of attention. The researchers did follow this up to an extent by considering the correlations between learning outcomes with performance on an attention task (Erickson et al., 2015), which provided objective measures of sustained selective attention in the same group of children. In addition to this, during this follow-up they tracked the eye-movements of the children while they completed the task. They found that accuracy on the attention task (validated by both behavioural and eye-tracking data) was significantly related to learning outcomes, in that higher accuracy indicated higher learning gains, and more fixations to distractor items indicated poorer learning outcomes. This suggests not only that attention is important for learning in typical development, but that aspects of the visual classroom environment may impact on attention and subsequently learning.

Few studies have investigated this relationship in autism. Hanley et al. (2017) investigated the impact of distraction upon learning in children with and without autism, using a video lesson, during which eye-movements of the participants were tracked. This enabled the examination of where children were looking during the lesson, and how this impacted how much they learned from the lesson. Each video consisted of a “teacher” delivering a 5-minute lesson on the topic of Irish myths and legends, and after each lesson the children completed a worksheet to measure their learning. Children watched two experimental lesson videos, at the start of which they were explicitly told to pay attention as they would be asked questions about it at the end. The background of each video was manipulated, similarly to the classrooms described in Fisher et al. (2014), to either be completely sparse (no visual distraction), or to include a high amount of visual displays (high visual distraction) taken from real primary school classrooms. The purpose of this was to measure the impact of the visual classroom environment upon attention (measured using eye-tracking) and learning during the lesson. Researchers were also interested in whether this impact on attention and learning was the same or different for children with autism compared to TD children. They found that the visual displays impacted on attention during the lesson for all children, but more so for children with autism in that the latter spent more time looking at the background, rather than at the teacher, compared to TD children. Furthermore, time spent looking at the background was the strongest predictor of learning outcome, alongside verbal ability and autism symptoms, suggesting that a higher proportion of time looking at the background led to poorer learning outcomes for all children.

Taken together, it may be the case that attentional atypicalities explain some of the variability in learning outcomes in autism. If it is the case that a child has poor attention alongside other factors that influence learning, this could further compound their ability to learn in school. Previous research has found some evidence of this, but measures of attention vary. Furthermore, little research has investigated the specific components of attention in relation to learning in autism. An in-depth investigation of this potential relationship is therefore necessary, including a comparison with TD children.

1.4 Aims of this thesis

As described above, and reviewed in detail in the following chapter, little research has considered the relationship between attention and learning in autistic children, despite evidence that suggests atypicalities of both attention and learning exist. There are many ways in which attention has been measured in TD children, although most studies of attention in autism often use only a single method. An effective way to investigate this in detail is therefore to adopt a multiple and mixed methods approach, using a variety of measures of attention and learning, in addition to using both quantitative and qualitative methodologies. It is also important to recognise the heterogeneity of cognition and behaviour in autism when designing research, and analysing and interpreting data (Charman, 2015).

The main aim of this thesis is to investigate the relationship between attention and learning in primary school pupils with ASD. Importantly, the same relationship in TD children will be investigated, to allow for some comparison between groups. A second aim is to take an approach that recognises the heterogeneity in ASD, accounting for differences in academic outcomes and in attention when examining the relationship between these factors. A final aim is to use multiple methods, in order to gain a rich and in-depth understanding of this relationship. The thesis will therefore include studies using standardised assessments (Chapter Three), computerised tasks (Chapter Four), eye-tracking techniques (Chapter Four), qualitative interview methods (Chapter Five), and parent questionnaires in terms of links with sensory processing and anxiety (Chapter Six).

Chapter Two: Predicting academic outcome for children with and without autism – a narrative review of the relationship between attention and achievement

2.1 Introduction

As outlined in Chapter One, attention atypicalities are known to exist in autism. Also briefly touched upon was the issue of academic outcomes for autistic individuals, and the relationship between attention and learning. This chapter offers a detailed review of the literature regarding attention as a predictor of academic achievement in both ASD and TD children. This review will focus on both evaluating evidence of the relationship between attention and achievement, as well as a discussion of the measurement tools used within the literature.

2.1.1 Outcomes for individuals with Autism Spectrum Disorder

Outcomes for individuals with an ASD are highly variable; for some, their prognosis improves from childhood to adulthood, whereas for others they maintain a stable trajectory, or in some cases even deteriorate (Levy & Perry, 2011). Factors affecting outcomes are vast, from autism severity and cognitive functioning, to access to interventions and support. Although a variety of outcome measures such as occupation, independent living, and social integration have been examined for individuals with ASD, there is a paucity of research that considers academic achievement as an outcome measure. Around 50-60% of individuals with ASD leave school without formal academic qualifications (Chung, Luk, & Lee, 1990), and very few complete further or higher education qualifications (Eaves & Ho, 2008), however few studies have considered the factors that may influence academic achievement. A recent review of the literature from Keen, Webster and Ridley (2016) identified 19 papers that studied academic achievement in relation to i) predictors of achievement, ii) identifying areas of academic strengths or weaknesses, or iii) considering levels of academic achievement for different sub-samples (i.e. ASD subtypes and TD comparisons). They found that levels of academic achievement varied dramatically in ASD, and that many individuals demonstrated academic strengths and weaknesses in particular domains. For example, at the individual level, reading achievement scores varied from "significantly below average" to scores considered to be in the "gifted" range. However, low ability groups, where IQ scores were less than 80, appeared to achieve relatively higher scores for reading achievement in relation to their mean IQ, suggesting that reading was a relative strength (Mayes-Dickerson & Calhoun, 2003a, 2003b). Interestingly, they also found that for individuals who were considered to be high-functioning (HFA), reading comprehension seemed to be a relative weakness; compared to their non-verbal IQ matched peers, they scored poorly on measures of reading comprehension

(Troyb et al., 2014). This suggests that both between- and within-individuals with ASD, there is a significant variation in academic performance, highlighting the need to provide academic support that is centred on the needs of the individual and their profile of strengths and weaknesses.

To understand how to improve academic outcome for individuals with ASD, it is vital to first understand the factors that may influence academic achievement. Keen et al. (2016) reported that a variety of factors were predictive of academic achievement, within the small section of the literature that considers this relationship (eight studies in total). Among the potential predictors of academic achievement were autism symptomology (Ashburner, Zivani, & Rodger, 2008; Eaves & Ho, 1997), cognitive ability (Mayes-Dickerson & Calhoun, 2008; Assouline et al., 2012), and environmental factors such as educational setting (Kurth & Mastergeorge, 2010) and participation in gifted and talented programmes (Assouline et al., 2012). Although this suggests that many factors may influence how individuals with ASD perform academically, research for each of these potential predictors is limited. It is therefore important that further research is conducted to gain a better understanding of how these factors may influence academic achievement.

2.1.2 Attention and academic achievement

Although research into factors related to academic achievement is already limited, one factor that is largely under-represented in the ASD literature is the role of attention. As referred to in Chapter One, the ability to focus and sustain attention is crucial for learning and subsequently for academic achievement (Erickson, Thiessen, Godwin, Dickerson, & Fisher, 2015; Fisher, Godwin, & Seltman, 2014; McKinney, Mason, Perkerson, & Clifford, 1975; Oakes, Kannass, & Shaddy, 2002; Yu & Smith, 2012). With this in mind, it is appropriate to consider whether attention skills are related to academic achievement, and although this relationship has been considered within TD populations, it has been severely overlooked within ASD research. Therefore, the aim of this narrative review is to consider the existing literature in relation to attention as a predictor of academic achievement for individuals with ASD. In order to do so, it is also vital to consider how attention and academic achievement are related for TD individuals. Making this comparison provides context to the research conducted with ASD samples, and demonstrates how under-researched this group is in relation to attention and academic achievement.

Many studies have attempted to assess whether or not attention predicts academic achievement, or in other words, whether children who are inattentive perform worse academically. It is important to distinguish between studies that use behavioural ratings of attention (e.g. Child Behavior Checklist; Conners' Rating Scales) and cognitive measures of attention (e.g. Woodcock-Johnson Pair Cancellation Task; visual search tasks). While one approach uses observations to measure the behavioural manifestation of an individual's attention, the other takes a direct measure of attention at the cognitive level. Despite the suggestion that these two measures are related (Rezazadeh, Wilding, & Cornish, 2011; Wilding, 2003; Wilding, Munir, & Cornish, 2001), it is important to acknowledge that they are measuring different aspects of attention, and should therefore be considered separately. Within the literature that considers attention as a predictor of academic achievement, the majority focus on measuring attention at the behavioural level (i.e. Does the child listen in class? Are they focused on tasks?), but some consider attention at the cognitive level. It is also important to consider the variety of different measures used within the literature, both of attention and of academic achievement. Although each claim to be measuring the same concept, we cannot be certain that this is the case.

The aims of this review are therefore: to provide a synthesis of the different measures of attention and academic achievement used within the literature, and to evaluate whether attention is predictive of academic achievement in TD children and children with ASD.

2.2 Method

2.2.1 Search terms and strategy

The literature search was carried out using the following online databases: Web of Science, Psychinfo, Psychology & Behavioural Sciences Collection, and ERIC. Primary search terms included combinations and variations of "attention", "academic achievement", "educational outcome" and "attainment". When searching for autism papers, additional search terms "autism" and "autism spectrum disorders" were used.

2.2.2 Inclusion and exclusion criteria

Searches conducted via the above databases were restricted to empirical research papers published in English, in peer-reviewed journals, between 1960 and 2019. The review considered research that examined attention as a predictor of some form of academic achievement (e.g. reading and/or maths achievement, academic grades) in children within TD or ASD samples. Studies using either behavioural ratings or cognitive measures of attention were included in the review. Studies were excluded if they:

- Examined other developmental groups (i.e. not TD or ASD). In cases where a study examined multiple groups, we have reported results only from the TD and/or ASD samples.
- Administered the attention measure with participants with a mean age of 18 years or above. Studies that predicted adult outcomes from childhood measures were included.
- Used ADHD diagnosis or symptoms as a predictor of outcome. Studies that used ADHD subtype symptoms (e.g. inattentiveness, hyperactivity, impulsivity) as behavioural indicators of attention, to individually predict outcomes, were included.
- Were not published in a peer-reviewed journal (e.g. grey literature, books).
- Were not written in English.
- Were reviews, commentaries, conference abstracts, or unpublished research thesis.

2.2.3 Study selection

An initial screening of titles and abstracts determined the eligibility of studies. A secondary evaluation of the full text of the remaining shortlisted studies was then conducted in compliance with the inclusion and exclusion criteria. Reference lists were also screened for additional studies for potential inclusion.

2.2.4 Synthesis of data

From all included studies, the following data were extracted and collated: sample size; participant characteristics including age and developmental status (i.e. TD or ASD); predictor and outcome variables; assessment measures used; and overall findings. Extracted data were integrated using a narrative synthesis approach, which allowed a summary and interpretation of the synthesised findings.

2.3 Results

The combined searches identified 873 studies, of which 761 studies were excluded in the first stage of screening titles and abstracts. Of the remaining 112 studies, a further 80 were excluded based on the requirements of the inclusion criteria, and an additional five studies were identified by a review of reference lists. Following this, one further study was excluded, as it was a re-analysis of data reported in another paper. The process yielded a total of 36 qualifying studies, of which 33 provided data from only TD samples, and 3 provided data from ASD samples. The TD studies were then divided into two samples, based on their method of measuring attention; behavioural ratings (N = 28; see Table 2.1) or cognitive measures (N = 5; see Table 2.2). Characteristics of the papers with ASD samples are reported in Table 2.3. Studies that report data from both TD and ASD samples appear in both Tables 2.2 and 2.3.

2.3.1 Measures of attention and academic achievement

2.3.1.1 Behavioural ratings of attention

Within this body of literature, there is significant variation between studies with regard to the attention measure that was used. What these studies have in common is that their aim was to determine whether attention is predictive of academic achievement, and they chose to measure attention using behavioural ratings, either by teacher report, parent report, self-report, or in some instances reported by the researcher. The majority of these studies considered attention under the umbrella of "behaviour problems", "externalising behaviours", or "inattention problems". The most commonly used behavioural rating measure within the literature (N = 9) was the Child Behavior Checklist (CBCL; Achenbach, 1991), with various versions being used dependent on the age of the sample and when the research was conducted. Another measure used in the literature (N = 2) is the Conner's Teacher or Parent Rating Scales (CRS; Conners, 1990), which consists of 28 items and measures inattention problems, oppositional behaviour problems, impulsive behaviour, and hyperactive behaviour. Although commonly used to assess these behaviours in children, Steele et al. (2012) made a pertinent point about the CRS and potential issues with its use in predicting academic achievement, particularly when measures include scores for reading and maths ability. They highlight that this measure includes some items relevant to literacy and numeracy (e.g. "Not reading up to par", "Poor in arithmetic") which could clearly influence the strength of the correlations between inattention scores and literacy or numeracy (academic) outcomes. Therefore, caution should be exercised by researchers when using CRS scores to predict such outcomes.

Another measure, used by three studies within the reviewed literature, is the Social Behavior Questionnaire (SBQ; Tremblay et al., 1991), which measures a range of behaviours from aggression to anxiety, with 4 items measuring inattention. The Strengths and Weakness of ADHD-Symptoms and Normal-Behavior (SWAN; Swanson et al., 2006) was also utilised by two studies, the most recent version of which has 18 items based on DSM-5 criteria to assess symptoms of inattention and hyperactivity/impulsivity. Other measures used by just one study within the reviewed literature included the Eyberg Child Behavior Inventory (Robinson, Eyberg, & Ross, 1980), the Infant-Toddler Social and Emotional Assessment (ITSEA; Briggs-Gowan & Carter, 2006), and the Colorado Child Temperament Inventory (CCTI; Rowe & Plomin, 1977).

Table 2.1. Studies using behavioural measures of attention with typically developing samples

Author (year)	N	Age at testing time-points	Study aim(s)	Measure(s) of Academic Achievement	Measure(s) of Attention	Findings	Comments on design rigor
Brennan et al. (2012)	566	T1: 2.5, T2: 4.5, T3: 7.5	To longitudinally examine whether toddler-age externalising behaviours (inattention, hyperactivity-impulsivity, oppositionality and aggression) are predictive of academic achievement at early school age. Also, to examine whether assignment to a parenting-focused intervention impacted academic achievement.	Academic achievement: Woodcock-Johnson Tests of Achievement III Academic Skills cluster	Child Behavior Checklist Eyberg Child Behavior Inventory	Inattention at age 4-5 was correlated to, but did not predict, academic achievement at age 7.5	Due to intervention element, sample comprised of children who met criteria for being “at risk” of future behaviour problems
Breslau et al. (2009)	693	T1: 6, T2: 17	To longitudinally examine which types of childhood behavioural problems predict academic achievement	Maths achievement: Woodcock-Johnson Psycho-Educational Battery-Revised Broad Math composite Reading achievement: Woodcock-Johnson Psycho-Educational Battery-Revised Basic Reading composite	Achenbach’s Teacher Report Form (TRF)	Attention problems at age 6 predicted math and reading achievement at age 17	Attention measure also includes items on hyperactivity and impulsivity

Claessens and Dowsett (2014)	16,260	T1: 5, T2: 6, T3: 8, T4: 10	To longitudinally examine the relationship between disruptive behaviour, attention problems, and academic achievement from kindergarten to elementary school.	Reading and math assessments, designed for the Early Childhood Longitudinal Study (Tourangeau et al., 2006)	Social Rating Scale (selected items from the Approaches to Learning subscale and Externalizing Problem Behavior Scale)	Classroom attention problems in kindergarten predicted reading and maths achievement in third grade	Different teachers reported attention at each timepoint
Dally (2006)	132	5.58 (first assessed)	To investigate whether kindergarten inattentive behaviour and phonological processing influences reading performance	Reading achievement: Woodcock Reading Mastery Tests – Revised Burns/Roe Informal Reading Inventory	Parent and Teacher ratings using the Rowe Behavioural Rating Inventory (five items)	Kindergarten measures of inattentiveness (teacher-rated only) and phonological abilities predicted reading performance, but this was mediated by word identification.	Only teacher ratings of inattentiveness were associated with reading outcomes. Parent ratings were omitted from the regression model.

Duncan et al. (2007)	Full sample size unreported	Ages not reported for all data sets. T1 ranged approx. from 4.5 to 6, T2 ranged from approx. 8 to 14	Meta-analysis to examine links between school-entry academic skills, attention, socio-emotional skills, and later reading and math achievement. Used six longitudinal data sets.	Set 1: Reading and math assessments, designed for the Study (Tourangeau et al., 2006) Set 2: Peabody Inidividual Achievement Tests (Reading and maths) Set 3: Woodcock-Johnson Psychoeducational Battery- Revised (Reading and Maths) Set 4: Woodcock-Johnson Tests of Achievement (Reading and Maths) Set 5: Unreported Verbal Skills and Number Knowledge test Set 6: Edinburgh Reading Test, University of Bristol Math Test	Set 1: Social Rating Scale (selected items from the Approaches to Learning subscale) Set 2: Hyperactivity Set 3: Continuous Performance Task, Child Behavior Checklist Set 4: Achenbach Child Behavior Profile Set 5: Unreported attention and hyperactivity ratings Set 6: Rutter Scale	Attention skills predict reading and maths achievement	Different tools used to measure attention and achievement between samples Sample includes some children within clinical range of behavioural problems

Fergusson and Horwood (1995)	709	T1: 8, T2: 10, T3: 11, T4: 12, T5: 13, T6: 15	To longitudinally examine the relationship between age 8 externalizing behaviours (conduct problems and attention deficit) and IQ, age 10 to 13 academic achievement, and delinquent behaviour to age 15.	Age 10/12: Progressive Achievement Test (PAT) Age 11: Progressive Achievement Test of mathematics Age 13: Test of Scholastic Abilities (TOSCA)	Maternal and teacher ratings based on a combination of the Rutter Scale and Conners' Rating Scale	Two developmental sequences emerged: (1) early conduct problems predicted later delinquency but not academic achievement, (2) attention deficit and IQ predicted later school achievement but not delinquency.	The items used to rate inattention are not reported, so may include hyperactivity and/or impulsivity items
Fleming et al. (2005)	576	T1: 12, T2: 16	To longitudinally assess whether youth problem behaviours are predictive of academic achievement.	Academic achievement: Washington Assessment of Student Learning (WASL) Grades (self-report question "In general what are your grades like this year?" with responses from 0 – 4, where 2 = "Mostly C's")	Items from the Teacher Observation of Classroom Adaptation-Revised and the Child Behavior Checklist (CBC). Teacher report items N = 5, Child report items N = 2.	Attention problems, negative peer behaviour and disruptive and aggressive behaviour predicted WASL scores and grades.	Regression models not fully reported, therefore the contribution of attention problems is unknown

Gray et al. (2014)	359	T1: 2, T2: 3, T3: 8	To longitudinally examine the relationship between early externalizing behaviour and academic achievement.	Reading achievement: Woodcock-Johnson Tests of Achievement III Broad Reading composite	Attention Scale items (N=5) from the Infant-Toddler Social and Emotional Assessment (ITSEA)	Early inattention predicted later reading achievement.	Ratings from only 5 items used to measure attention
Gray et al. (2015)	204	7.7 (first assessed)	To determine whether working memory mediates the relationship between inattentive behaviour and academic outcomes one year later.	Maths achievement: AIMSweb M-CBM, Mathematics Curriculum-Based Measurement (addition and subtraction) Woodcock-Johnson Tests of Achievement III: Math Calculation Reading achievement: Dynamic Indicators of Basic Early Literacy Skills: Oral Reading Fluency Woodcock-Johnson Tests of Achievement III: Letter Word Idenfitication	Inattention subscale of the Strengths and Weakenesses of Attention-Deficit/Hyperactivity Disorder Symptoms and Normal Behaviour Scale (SWAN)	Inattention and working memory longitudinally predicted math achievement but not reading achievement.	The sample included children with ADHD (5.5%), language impairment (4.9%), learning disability (3.8%) and behaviour difficulty (1.6%)

Grills-Taquechel et al. (2013)	161	7.3 (end of year age)	To concurrently and longitudinally examine: (1) the relationship between anxiety, inattention and academic achievement, (2) the mediating/moderating role of inattention in the relationship between anxiety and academic achievement	Reading achievement: Woodcock-Johnson Tests of Achievement III Basic Reading composite and Passage Comprehension subtest Maths achievement: Woodcock-Johnson Tests of Achievement III Calculation subtest	Inattention subscale of the Strengths and Weakenesses of Attention-Deficit/Hyperactivity Disorder Symptoms and Normal Behaviour Scale (SWAN)	Inattention at mid-year and year-end was strongly related to year-end achievement scores. Inattention significantly predicted achievement	Anxiety scales were also entered in regression model
Holmberg and Bolte (2014)	544	T1: 7, T2: 10, T3: 16	To assess the efficiency of a behavioural screening with the Conners 10-item at ages 7 and 10 to predict academic achievement at age 16.	Final school grades registered in the National School Register (Sweden)	Conners 10-item scale – inattentive items: fails to finish tasks inattentive and easily distracted	The inattentive items were the strongest predictors of final grades.	Inattention rating based on two items from hyperactivity scale
Jaekel, Wolke and Bartmann (2013)	567	T1: 6.25, T2: 8.5, T3: 13	To investigate whether attention or hyperactivity/impulsivity problems at middle childhood are better predictors of academic achievement for very preterm and full-term adolescents.	Level of educational track in the German secondary school system (based on type of school attended, whether they are in an age appropriate class, and their performance in Maths and German) – 9-point ranking scale	Tester's Rating of Child Behaviour (TRCB) Evaluation by the research team	Childhood attention (and not hyperactivity/impulsivity) predicted academic achievement in both very	Variety of attention measures used, all but one of which predicted academic achievement

					Observations of child activity and task persistence Child Behaviour Checklist	preterm and full term adolescents.	in full term sample
Martin and Holbrook (1985)	104	6.8	To explore the relationship between temperament (activity level, adaptability, approach or withdrawal, emotional intensity, persistence and distractibility) and achievement.	Reading achievement and Maths achievement: Reading and Maths end of year grades Reading and Maths scores from American School Achievement Test (ASAT)	Distractibility Scale from the Teacher Temperament Form of the Temperament Assessment Battery	Persistence, adaptability and distractibility predicted reading grades. Distractibility did not predict maths grades, or the reading or maths ASAT scores.	Participants were from a single school in a low-income area
McClell and et al. (2013)	430	T1: 4, T2: 7, T3: 21	To examine the relationship between preschool attention span-persistence and later school achievement.	Reading achievement: The Peabody Individual Achievement Test (PIAT) Reading Recognition subtest Maths achievement at age 7: Wechsler Intelligence Scale for Children-Revised (WISC-R) Arithmetic subscale Maths achievement at age 21: Wechsler Adult Intelligence Scale III (WAIS-III) Arithmetic subscale	Colorado Child Temperament Inventory (CCTI) – Attention Span-Persistence subscale (5 items)	Age 4 attention span-persistence predicted maths and reading achievement at age 21.	Ratings from only 5 items used to measure attention span-persistence

Meyers, Attwell and Orpet (1968)	57	T1: 6, T2: 10	To examine what factors predict academic achievement.	Unreported battery. Measures of: Reading Words, Reading Comprehension, Arithmetic Reasoning, Arithmetic Fundamentals, Mechanics of English, Spelling, Total Achievement.	A single 9-point scale item rated by the experimenter (unreported)	Attention was the strongest predictor for Reading Words, Reading Comprehension and Spelling, and was the second strongest predictor of Total Achievement.	Only a single item used to measure attention
Pagani et al. (2010)	1145	5.4 (first assessment)	To longitudinally examine potential predictors of academic achievement.	Teachers ratings on 5-point scale for: Reading achievement Maths achievement General achievement	3 items from the Social Behaviour Questionnaire measuring Attention Skills	Attention skills predicted maths, reading and general achievement.	Achievement was estimated by teachers Teachers rated both achievement and attention

Pagani & Fitzpatrick (2014)	1752	T1: 5, T2: 10	To predict children's health behaviours and academic adjustment at the end of forth grade from kindergarten entry math, vocabulary and attention skills.	Maths achievement: Canadian Achievement Test of Mathematics Teacher estimates of reading, maths, spelling, science and global achievement on 5-point Likert scale	9 items from the Social Behaviour Questionnaire	Attention skills and vocabulary made significant contributions to predicting achievement at age 10, kindergarten maths skills was a stronger predictor.	Attention measure included hyperactivity and impulsivity items
Pham (2016)	131	9.13 (mean) 8 – 11 (range)	To determine how each domain of ADHD (inattention, hyperactivity, impulsivity) contributes to reading achievement	Reading fluency and comprehension: Gray Oral Reading Test-Fourth Edition	Swanson, Nolan and Pelham-Version Four (SNAP-IV) inattention subscale	Inattention significantly predicted reading fluency, reading comprehension and overall reading ability	Both teachers and parents provided ratings of inattention

Pingault et al. (2011)	2000	T1: 6, T2: 7, T3: 8, T4: 9, T5: 10, T6: 11, T7: 12, T8: 21	To differentiate the longitudinal contributions of inattention and hyperactivity symptoms to educational attainment.	Whether or not participants had a high school diploma	3 items from the Social Behaviour Questionnaire measuring Attention Skills	A high inattention trajectory strongly predicted not having a high school diploma at 22-23, compared to low inattention. Hyperactivity was not a significant predictor	Four items used to assess attention Groups (i.e. those who did have a high school diploma, those that did not) were not balanced
Rabiner and Coie (2000)	387	Not reported – approx. 4, 5, 10	To determine whether attention problems predict the development of reading difficulties.	Reading achievement: Woodcock-Johnson Psychoeducational Battery-Revised Letter-word identification and Passage Comprehension subtests	Child Attention Problems Scale – 7 inattentive items	Attention problems predicted reading achievement, even after controlling for prior reading achievement, IQ and other behavioural difficulties.	Mean age not reported, only grade of children at testing time-points given

Romano et al. (2010)	1521	T1: 5, T2: 7	To examine the relationship between kindergarten socioemotional behaviours and later school achievement.	Reading achievement: Mother-reported single item on 5-point scale Maths achievement: Mathematics Computation Exercise, abridged version of the math operations test from Canadian Achievement Tests	3 items from the Social Behaviour Questionnaire measuring Attention Skills	Attention skills predicted reading but not maths. Maths skills were the strongest predictor of later achievement.	Mothers reported both reading achievement and attention skills
Rudasill, Gallagher, and White (2010)	707	T1: 4.5, T2: 8.9	To examine the interplay of children's temperamental attention and activity and classroom emotional support, and their relation to third grade academic achievement.	Reading achievement: Woodcock-Johnson Psychoeducational Battery-Revised Broad Reading composite Maths achievement: Woodcock-Johnson Psychoeducational Battery-Revised Broad Maths composite	Temperamental attention: Children's Behaviour Questionnaire	Classroom emotional support moderated the relationship between attention and reading and maths achievement.	Information about whether children had clinical diagnosis of attention disorders was not collected

Salla et al. (2016)	1173	T1: 1.5 to 5 T2: 6 to 10 T3: 12	To investigate whether the developmental trajectories of inattention and hyperactivity symptoms during childhood are independently associated with academic achievement at age 12.	Exam results for reading, writing and mathematics Teacher report of student's average in reading, writing and mathematics	Childhood Behaviour Questionnaire	High childhood trajectories were associated with academic performance	Mothers and teachers both provided ratings of inattention
Sarver et al. (2012)	317	10.7 (mean) 7 – 16 (range)	To examine individual differences in phonological and visuospatial short-term memory as potential mediators of the relationship between attention problems and scholastic achievement.	Near-term scholastic achievement: Kaufman Test of Educational Achievement Brief Form Long-term scholastic achievement: Stanford Achievement Test	Child Behaviour Checklist – Teacher Report Form	Attention problems were negatively related to scholastic achievement, but this influence was attenuated to phonological and visuospatial short-term memory	Wide age range used

Serbin, Stack and Kingdon (2013)	127	Unreported, approx. 11, 13	To longitudinally investigate predictors of academic performance in grades 7-8 with adolescents from low-income backgrounds.	Grade Point Average (GPA) – 4-point scale (average of grades in French, Maths, Humanities/Social Studies, Science and English)	Child Behaviour Checklist – Teacher Report Form	Inattention predicted academic performance.	Ecological measure of academic achievement used, derived from grades for multiple subjects
Sijtsema et al. (2014)	2230	T1: 11.1, T2: 13.6	To examine the influence of psychopathology and functioning at school upon academic performance.	Academic performance: teacher report questionnaire developed by TRAILS	Youth Self Report Child Behaviour Checklist Teacher Ratings of Psychopathology	Attention problems were the strongest predictor of poor academic performance.	Multi-informant measures of attention used (self-, parent- and teacher-report)
Stipek and Valentino (2015)	5873	Unreported. From 4 through 14 years.	To longitudinally assess how well early childhood measures of short-term memory, working memory and attention predict maths and reading comprehension.	Maths and Reading comprehension: Peabody Individual Achievement Test	Behaviour Problems Index – hyperactivity subscale	Attention, digit span, and verbal memory predicted maths and reading comprehension.	Hyperactivity subscale used to measure attention

Veldman et al. (2014)	1711	T1: 11, T2: 19	To examine if mental health problems at age 11 predict educational attainment at age 19, and if changes in mental health problems between age 11 and 16 predict educational attainment at age 19.	Attainment: Categorised participants into groups of low, medium and high attainment, based on highest diploma obtained or current educational level	Attention problems: combination of YSL and CBCL items	Attention problems at age 11 predicted attainment at age 19. Changes in attention problems did not predict attainment at age 19.	Multi-informant measures of attention used (self- and parent-report)

Table 2.2. Studies using measures of cognitive attention to predict academic achievement in typically developing children

Author (year)	N	Age at testing time-points	Study aim(s)	Measure(s) of Academic Achievement	Measure(s) of Attention	Findings	Comments on design rigor
Colom et al. (2007)	135	13.4	To concurrently consider several cognitive and personality measures (fluid intelligence, short-term memory, working memory, processing speed, controlled attention, temperament difficulties) as predictors of academic performance.	Students' average grades in their 9 subjects: nature sciences, social sciences, Spanish, English, mathematics, music, technology, gymnastics, and modelling arts.	Controlled attention – using a flanker task (Eriksen & Eriksen, 1974)	Controlled attention did not predict academic achievement, though fluid intelligence and memory span played a role in predicting academic performance, as did impulsiveness, sensation seeking, and a lack of fear.	Several factors were used as predictors, which may have weakened the predictive power of attention
Dulaney, Vasilyeva, & O'Dwyer (2015)	1364	4.5, then grades 1, 3, 5	To investigate the extent to which early measures of attention and short-term storage predict differences in mathematics achievement.	Woodcock-Johnson Tests of Achievement Applied Problems subtest	Performance based attention: Continuous Performance Task Parent report attention: Child	Short-term storage and performance based (i.e. executive/controlled) attention significantly predicted	Only one maths subtest used, rather than a composite score from multiple subtests

					Behavior Checklist	differences in maths achievement.	
Lan et al. (2011)	258	5	To examine whether three subcomponents of executive function (working memory, inhibition, and attentional control) are linked to academic achievement, and whether there are cultural differences in this relationship.	Reading achievement: USA: Woodcock-Johnson Tests of Achievement Letter-word identification China: 61-item Chinese character recognition task Maths achievement: USA: Woodcock-Johnson Tests of Achievement Applied problems China: ZAREKI-KP task	Woodcock-Johnson Pair Cancellation Task from Woodcock-Johnson Test of Cognitive Abilities III	Attentional control strongest predictor of reading achievement for all children, but it only partially predicted maths achievement, predicting calculation but not counting.	Different measures of reading and maths achievement were used for the two groups
Mayes & Calhoun (2007)	149	Range from 6 to 16	To investigate the relationships between learning, attention, graphomotor and processing speed and determine differences between diagnostic groups.	Reading achievement: Wide Range Achievement Test – Third Edition Reading subtest Maths: Wide Range Achievement Test – Third Edition Arithmetic subtest	Controlled attention: Gordon Diagnostic System Vigilance and Distractibility subtests Wechsler Intelligence Scale	Attention made a significant contribution to the variance accounted for in both maths and reading achievement, though IQ was the strongest predictor.	Two different measures used to assess controlled attention

					for Children Digit Span subtest		
					Attentional switching:		
May, Rinehart, Wilding & Cornish (2013)	60	Range from 7 to 12	To test the associations between inattentive and hyperactive-impulsive symptoms, attentional switching, sustained attention, and gender in academic achievement.	Reading achievement: WIAT-II Word Reading subtest Maths achievement: WIAT-II Numerical Operations subtest	Visearch task from Wilding Attention Tasks dual-target version Sustained attention: Vigilan task from Wilding Attention Tasks	Attentional switching and sustained attention did not predict maths or reading achievement.	Subtests of the WIAT-II used rather than composite scores of reading and maths achievement
May, Rinehart, Wilding & Cornish (2014)	40	Range from 8 to 13	To explore how literacy, numeracy and attentional skills develop over one year.	Reading achievement: WIAT-II Word Reading subtest Maths achievement: WIAT-II Numerical Operations subtest	Attentional switching: Visearch task from Wilding Attention Tasks dual-target version	Attentional switching and sustained attention did not predict Time 2 maths and reading achievement, after accounting for achievement scores at Time 1.	As per May et al. (2013)

					Sustained attention: Vigilan task from Wilding Attention Tasks Attention Sustained Task from the Leiter International Performance Scale-Revised provided two measures:		
Razza, Martin and Brooks-Gunn (2012)	2595	Two time-points: 5, 9	To longitudinally examine the relationship between attentional regulation in preschool and school success in elementary school.	Reading achievement: Woodcock-Johnson Tests of Achievement III Passage Comprehension Maths achievement: Woodcock-Johnson Tests of Achievement III Applied problems Approaches to Learning: scale derived from ECLS-K study	Focused attention: number of correct responses Lack of impulsivity: number of incorrect responses	Focused attention predicted all achievement outcome measures. Lack of impulsivity predicted approaches to learning only.	Single subtests used as outcome measures, rather than composite scores from multiple subtests
Steele et al. (2012)	83	Four groups: 3.4, 4.5, 5.6, 6.6 at first	To concurrently and longitudinally assess whether attentional processes (executive attention, sustained-selective	Literacy: Phonological Abilities Test	Selective-sustained attention: continuous performance task	Executive attention concurrently predicted literacy and numeracy. Longitudinally,	Small sample size, only 20-22 children per group

assess ment, then assesse d 12 months later	attention) predict literacy and numeracy.	British Picture Vocabulary Scale II Early Word Reading ability scale / British Ability Scale II - Single World Reading subtest (if score > 34 on EWR) Numeracy: The “give-a-number” protocol (Wynn, 1990) Test of Early Mathematics Ability III	and visual search task Executive attention: Spatial Conflict task Attention problems: Conners' Teacher Rating Scale - Revised	sustained-selective attention predicted basic numeracy but not single word reading.

Table 2.3. Studies using attention to predict academic achievement in children with ASD

Author (year)	N	Age at testing time-points	Control group details	Study aim(s)	Measure(s) of Academic Achievement	Measure(s) of Attention	Findings	Comments on design rigor
Mayes & Calhoun (2007)	118	6-16 years	149 TD children matched on age	To investigate the relationships between learning, attention, graphomotor and processing speed and determine differences between diagnostic groups.	Reading achievement: WIAT Word Reading and Reading Comprehension subtests Maths: Wechsler Individual Achievement Test Numerical Operations subtest	Control led attention: Gordon Diagnostic System Vigilance and Distractibility subtests Wechsler Intelligence Scale for Children Digit Span subtest	Attention made a significant contribution to the variance accounted for in both maths and reading achievement, though IQ was the strongest predictor.	Two different measures used to assess controlled attention
May, Rinehart, Wilding & Cornish (2013)	64	7-12 years	60 TD children matched on perceptual IQ	To test the associations between inattentive and hyperactive-impulsive symptoms, attentional switching, sustained attention, and gender in academic achievement.	Reading achievement: WIAT-II Word Reading subtest Maths achievement: WIAT-II Numerical Operations subtest	Attentional switching: Visearch task from Wilding Attention Tasks dual-target version Sustained attention:	Attentional switching predicted maths achievement, but none of the attention measures predicted reading achievement.	Outcome measures were subtests of the WIAT-II rather than composite scores of reading and maths achievement.

						Vigilan task from Wilding Attention Tasks		
May, Rinehart, Wilding & Cornish (2014)	40	8-13 years	40 TD children matched on age and perceptual IQ	To explore how literacy, numeracy and attentional skills develop over one year.	Reading achievement: WIAT-II Word Reading subtest Maths achievement: WIAT-II Numerical Operations subtest	Attentional switching: Visearch task from Wilding Attention Tasks dual-target version Sustained attention: Vigilan task from Wilding Attention Tasks	Attentional switching and sustained attention did not predict Time 2 maths and reading achievement, after accounting for achievement scores at Time 1.	As per May et al. (2013)

Quite clearly, before the findings of this research have even been considered, a significant issue with the literature is a lack of consistency across studies with regards to the measures used for behavioural ratings of attention. Not only are a wide variety of measures used, meaning that there can be no certainty that the same phenomenon is being measured, but they also vary with regards to the items used (e.g. inclusion of hyperactivity items). This raises concerns for interpreting the findings of the literature as a whole.

2.3.1.2 Cognitive measures of attention

Far fewer studies have used tasks that probe attention at the cognitive level to understand the potential role of attention in predicting academic achievement (N = 8). As a consequence, even fewer studies have used the same cognitive measure of attention, or even examined the same components of attention. As outlined in Chapter One, it is vital to distinguish between the different sub-functions of attention, as although they all fall under the same umbrella of attention, each aspect serves a different function. To complicate matters, authors often differ in their descriptions of these sub-functions, making interpretation of performance and how these attentional sub-functions map on to one another difficult. As discussed above in relation to behavioural ratings of attention, although two measures may claim to be measuring the same concept, this cannot be confirmed with any certainty due to the inconsistencies between measures. When drawing conclusions from the literature as a whole, therefore, it is important to be aware of the inconsistencies that may be present, not only in terms of the concept being measured and the tasks used to do so, but also in the findings of these studies. The aspects of attention measured within the existing literature are discussed below.

As described in Chapter One, the Continuous Performance Test (CPT) has been widely used to tap sustained attention in TD children and was used by two studies within the reviewed body of literature (Steele et al., 2012; Dulaney, Vasilyeva, & O'Dwyer, 2015). When the CPT is administered, participants are typically presented with single images on a computer screen, and asked to press a button each time a designated target image appears. Another measure used by one study in the literature to tap sustained attention is the Attention Sustained task from the Leiter International Performance Scale-Revised (Leiter-R; Roid & Miller, 1997), which is a standardised non-verbal measure of intelligence. For the Attention Sustained task, children are presented with a page scattered with images of objects, and are asked to draw a line through all objects that match a target at the top of the page. Two measures of attention are obtained reflecting the participant's focused attention (number of correct responses) and lack of impulsivity (number of incorrect responses). Although the CPT and Attention Sustained tasks yield comparable data, there are some differences in the designs; in the CPT, target and distractor items are presented in isolation, compared to the Attention Sustained task, in which participants are required to "search" for target items amongst distractors. This suggests that the level of interference may differ between tasks, and therefore they may not be tapping the same attentional processes. Due to the presence of distractors, the Attention Sustained task may in fact be tapping selective attention.

Only one study within this review measured selective attention (Steele et al., 2012), therefore only one task is described here. As described in Chapter One, visual search tasks require participants to search for and select target items amongst an array of distractor items. Steele et al. (2012) used a visual task that was presented on a touch-screen tablet so that the task was accessible to even very young children. Although this was the only study within the reviewed literature to measure selective attention, visual search tasks are a common occurrence in the wider selective attention literature.

Executive attention can be measured using tasks that require the participant to complete an objective while ignoring distractor items that may share properties with the target, leading to some conflict. One example of this is the flanker task, such as that used by Colom, Escorial, Shih and Privado (2007), in which participants are required to make decisions about the status of arrows and digits, while ignoring congruent and incongruent distractor items. Another task that has been used to measure executive attention, used by one study in this review (Lan et al., 2011) is the Woodcock-Johnson Pair Cancellation task from the Woodcock-Johnson III Tests of Cognitive Abilities (Woodcock, McGrew, & Mather, 2001a). This task involves searching for and circling a designated pattern of images (i.e. a ball followed by a dog) on a sheet of paper, amongst distractor images. Finally, Steele et al. (2012) used an adapted version of the Spatial Conflict Task, as outlined in the previous chapter. In adults, executive attention is necessary when resolving conflict between stimuli (Norman & Shallice, 1986), and adapted versions of this task have been used to measure spatial conflict in children as young as 24 months (Gerardi-Coulton, 2000). As these studies each measure executive attention using different tasks that may tap different aspects of executive attention, it is difficult to compare the data between studies.

There are clearly similarities between the tasks designed to measure the different elements of attention, however the subtle differences mean that we cannot be certain that they are measuring the same attentional process. Furthermore, there are many discrepancies between authors concerning the way in which attentional processes are defined; although studies may use the same term to describe an attentional process, they do not necessarily operationalise or measure them in the same way. Inevitably this means that the relationship between attention and academic achievement will vary between studies, even before taking into consideration the differences between samples, making it challenging to draw conclusions from the literature as a whole.

2.3.1.3 Measures of academic achievement

Similar to assessments of attention, the measures used to assess academic achievement vary considerably, with some using standardised assessments, and others using data such as student grades as a measure of academic achievement. For the standardised assessments, reading, maths and academic achievement were used as outcome measures. Ten studies used overall academic achievement scores, and some used reading (N = 21) and maths (N = 20) achievement scores, either in addition to or separately from the overall academic achievement score. By far the most frequently used standardised measure of achievement (N = 11) was the Woodcock-Johnson Tests of Achievement (Woodcock, McGrew, & Mather, 2001b), which can provide a composite academic achievement score, as well as separate maths and reading achievement scores. Another measure, used by three of the reviewed studies, is the arguably outdated Peabody Individual Achievement Test (PIAT; Dunn & Marwardt, 1970), which provides scores for maths and reading achievement. Seven studies chose more ecological measures of academic achievement, such as academic grades. Although from an ecological perspective it can be beneficial to use academic grades as a measurement of academic achievement, research that does so will lack the control that standardised measures of achievement can offer.

So far, the review has focused on measures of attention and academic achievement, and the potential issues that arise within the literature. The following sections will consider the question of whether attention predicts academic achievement for TD children, and for children with ASD.

2.3.2 Does attention predict academic achievement for typically developing children?

2.3.2.1 Behavioural ratings of attention

From the review of the literature, 28 studies were found to have attempted to assess whether behavioural ratings of attention are predictive of academic achievement, and on the whole, the findings of most studies concur. Although the majority (N = 20) found attention to be a significant predictor of some form of academic achievement (Breslau et al., 2009; Claessens & Dowsett, 2014; Duncan et al., 2007; Fergusson & Horwood, 1995; Fleming et al., 2005; Gray et al., 2014; Holmberg & Bolte, 2014; Jaekel, Wolke, & Bartmann, 2013; McClelland et al., 2013; Meyers, Attwell, & Orpet, 1968; Pagani et al., 2010; Pagani & Fitzpatrick, 2014; Pham, 2016; Pingault et al., 2011; Rabiner & Coie, 2000; Salla et al., 2016;

Serbin, Stack, & Kingdon, 2013; Sijtsema et al., 2014; Stipek & Valentino, 2015; Veldman et al., 2014), seven studies found that it is predictive of certain outcomes but not others (Gray et al., 2015; Martin & Holbrook, 1985; Romano et al., 2010), or that other variables play a role in the relationship (Dally, 2006; Grills-Taquechel et al., 2013; Rudasill, Gallagher, & White, 2010; Sarver et al., 2012). Only one study found no predictive relationship between the attention and academic achievement (Brennan et al., 2012). The following section will provide an overview of some of these studies, and discuss the implications.

One of the largest studies in the literature regarding predictors of academic achievement was a meta-analysis conducted by Duncan et al. (2007), who analysed data from six longitudinal studies. The total sample size was not reported, but based on the studies used it is estimated to be over 30,000. Of these six samples, five had data on behavioural ratings of attention, one of which also had cognitive attention data, and one with data on hyperactivity ratings. They also all measured some form of school-entry maths and reading skills, and socio-emotional behaviours, as well as a later measure of academic achievement. The age at which these assessments were carried out varied across studies, with some completing assessments of academic achievement at approximately 8 years (e.g. The Infant Health and Development Program), and others up to 14 years (e.g. The National Longitudinal Survey of Youth). Duncan and colleagues found that the strongest predictors of academic achievement were school-entry maths skills, with early language skills and attention also consistently predicting academic achievement. However, it should be noted that measures for both predictors and outcome variables varied across the six studies. Grimm et al. (2010) acknowledged this issue, and chose to reanalyse the data from three of the six studies used within the original meta-analysis. On the whole, their results supported those of the previous study, in that attention problems were strongly associated with academic achievement, however, there was variation between the samples. For one of the samples, there was no attention effect; the authors attribute this to the fact that parent-rated hyperactivity was used as a measure of attention.

Another large-scale study was conducted by Claessens and Dowsett (2014) who aimed to examine the relationship between attention problems, disruptive behaviour and academic achievement longitudinally, and consider whether changes in one domain predicted changes in another. Children were tested at several time points between the ages of 5 and 10 years. Unreported reading and maths assessments designed specifically for the study were used as measures of academic achievement. Attention problems were measured using selected items from the Approaches to Learning and Externalising Problem Behaviour subscales of the Social Rating Scale (Tourangeau et al., 2006). The authors found that classroom attention problems measured in kindergarten significantly predicted both third grade maths ($b = -1.56$, $p < .001$)

and reading achievement ($b = -1.22$, $p < .001$). Furthermore, changes in attention problems during kindergarten predicted changes in maths and reading achievement between first and third grade in that an increase in attention problems was associated with decreased reading and maths gains.

McClelland et al. (2013) considered the relationship between attention and academic achievement over a longer time frame, testing participants' attention span-persistence with the CCTI at age 4, and maths and reading achievement with the PIAT and Weschler Adult Intelligence Scale III (WAIS-III) at age 21. They found that attention span-persistence significantly predicted both maths ($\beta = .17$, $p < .001$) and reading achievement ($\beta = .14$, $p < .01$), suggesting that early inattention problems can influence academic achievement into early adulthood. Similarly, Holmberg and Bolte (2014) found that inattention at age 7, measured with item 4 ("fails to finish what he or she starts"; $\beta = -.22$) and item 3 ("disturbs other children"; $\beta = -.12$) from the parent CRS form predicted final school grades at age 16 ($R^2 = .09$, $F(2) = 18.7$, $p < .001$).

A small number of studies (N = 3) have found that despite attention predicting certain academic outcomes, it does not necessarily predict others. For example, Gray et al. (2015) found that inattention in 5 to 9-year-olds longitudinally predicted maths achievement one year later, accounting for 11.4% of the variance in addition fluency, but did not predict reading achievement. Interestingly, Martin and Holbrook (1985) found that for 6 and 7-year-olds, distractibility predicted end-of-year reading grades, but not maths grades or reading or maths scores from the American School Achievement Test. Other studies (N = 4) have found that attention does predict academic achievement, but that this relationship is mediated or moderated by other variables. For example, Rudasill, Gallagher, and White (2010) were interested in the role of classroom emotional support in the relationship between attention and academic achievement. The authors found that although attention at age 4.5 years predicted reading ($\beta = .14$, $p < .001$) and maths achievement ($\beta = .7$, $p < .001$) at age 8.5 years, this relationship was moderated by classroom emotional support; attention was more predictive of academic achievement for children in classrooms with lower emotional support. By comparison, Sarver et al. (2012) studied 7 to 16-year-olds and found it was phonological and visuospatial short-term memory that mediated the relationship between attention problems and academic achievement (model accounted for 53% of variance in achievement).

In contrast to all of the above, Brennan, Shaw, Dishion and Wilson (2012) found that although inattention at age 4.5 years was correlated to academic achievement at age 7.5 years, it was not a significant predictor. The authors did, however, find that aggression predicted academic achievement. It is important to consider that the sample consisted of children at "high-risk" for behavioural, family and socio-economic problems. This could explain why few predictive relationships were found between their behavioural measures and academic outcomes.

Generally, the literature suggests that children who are less attentive in the classroom perform worse academically, in relation to both reading and maths achievement. This is supported by a systematic review conducted by Polderman et al. (2010), who found that children with attention problems (i.e. symptoms of hyperactivity and inattentiveness) were at risk for lower academic achievement. Some variance exists within the literature with regards to whether or not this is the case, however as previously mentioned, the measures used to obtain behavioural ratings of attention and of academic achievement are highly inconsistent.

2.3.2.2 Cognitive measures of attention

Far fewer studies (N = 8) have investigated whether academic achievement is influenced by cognitive attention, the results of which are varied. Colom et al. (2007) investigated the predictive qualities of a variety of measures upon academic achievement in secondary school students. Alongside executive attention, the potential predictors they considered were memory span (encompassing fluid intelligence, short-term memory and working memory) processing speed, and three personality dimensions: sensation seeking, impulsiveness, and lack of fear. Academic achievement was measured using an overall score of students grades in their nine academic subjects combined, and executive attention, as previously described, was measured using a flanker task. Although the authors found that memory span and temperament difficulties accounted for 62% of the variance in overall academic performance, they found no relation with executive attention.

In contrast, despite using similar tasks to measure attention, Steele et al. (2012) found a relationship between attention and academic achievement in 3 to 6-year-olds. Rather than attempting to use a range of predictors, Steele and colleagues focused on considering the sub-functions of attention when attempting to assess its relation to academic achievement, both concurrently and one year later. They argue that because attention is comprised of separate but related processes, these processes should be considered separately when considering how it may influence academic performance. As such, they used tasks designed to measure sustained, selective and executive attention, in order to separate these attentional processes. As described above, the CPT and Visual Search task were used to measure sustained-selective attention, and the Spatial Conflict task measured executive attention. The authors also obtained behavioural ratings of attention using the Conners' Teacher Rating Scale – Revised: Short Version (CTRS-R:S; Conners, 1997). For concurrently predicting academic achievement, executive attention was found to be a significant predictor of both literacy (3.5% variance in vocabulary; 3% variance in letter knowledge) and numeracy (6.7% variance in cardinality; 3.8% variance in addition). Longitudinally, sustained-selective attention significantly predicted basic numeracy, accounting for 1.6% of the variance, but not literacy. In addition, classroom attention behaviours appeared to longitudinally predict literacy, however, as previously discussed, using CTRS-R:S scores to predict reading and maths ability may be problematic. Therefore, the authors repeated the regression analysis with scores from these items removed, and found that classroom attention behaviours no longer predicted reading or maths, suggesting that it was the items about these abilities that were driving this relationship. This raises clear issues with using the CTRS-R:S as a measure of attention.

Dulaney, Vasilyeva, & O'Dwyer (2015) also used the CPT to measure sustained attention in children aged 54 months. They also took behavioural ratings of attention, reported by the child's mother using the CBCL. Children's maths achievement was then assessed at 54 months, and in grades one, three and five using the Applied Problems subscale of the Woodcock-Johnson III Tests of Achievement. The authors were also interested in the role of storage, therefore an assessment of verbal short-term memory from the Woodcock-Johnson III Tests of Cognitive Abilities was also used. They found that both sustained attention and short-term memory predicted maths achievement at age 54 months, but that the behavioural rating of attention was not a significant factor in the model. The authors speculate that this inconsistency between the two attention measures could be due to informant reports not distinguishing inattention and hyperactivity sufficiently. They argue that this would mean that direct, performance-based measures of attention capture individual differences more accurately; the extent to which children exhibit overt behaviours that reflects their inattention can differ between subjects (Barkley, 1997), a subtlety which informant reports of attention may struggle to capture.

Studies examining the predictive ability of cognitive attention upon academic achievement using standardised assessments also exist in the literature. Lan et al. (2011) were interested in three subcomponents of executive function; specifically working memory, inhibition, and attentional control, and whether these are linked to academic achievement. Another aspect of this study was to investigate the cultural differences in executive function in younger children, therefore two samples from the United States and China were used. In the American sample, reading and maths achievement were measured using the Woodcock-Johnson Tests of Achievement III. For the Chinese sample, reading was measured with a Chinese character recognition task, and math abilities were measured using the ZAREKI-KP task (Von Aster, 2001). As previously mentioned, they used the Woodcock-Johnson Pair

Cancellation task to measure attentional control for both samples. They found that attentional control was the strongest predictor of reading achievement for all children (US sample $\beta = .12$; China sample $\beta = .27$) but that it only partially predicted maths achievement, predicting calculation (US sample $\beta = .21$; China sample $\beta = .18$) but not counting.

Razza, Martin and Brooks-Gunn (2012) focused more on attention as a single construct, rather than alongside other aspects of executive function, and its relationship with literacy and numeracy. Specifically, they wanted to know whether attentional regulation in preschool was longitudinally predictive of school success in elementary school in a sample of children from low-income backgrounds. Sustained attention was measured at approximately age 5 years using the Attention Sustained Task from the Leiter International Performance Scale-Revised. Measures of reading and maths achievement were obtained at approximately age 9 years by administering the Passage Comprehension and Applied Problems subtests of the Woodcock-Johnson III Tests of Achievement. They found that sustained attention longitudinally predicted both reading and maths outcomes, accounting for 3.7% of the variance in reading and 6.6% of the variance in maths; children who had higher scores for sustained attention achieved higher scores in reading and maths.

Although it is clear that there is considerable variability in the literature, most of the reported studies concur that attention predicts some form of academic achievement. This said, there are inconsistencies in relation to whether maths achievement, reading achievement, or both, are related to attention. It is possible that different attentional processes are associated with domain-specific skills, and are therefore predictive of different academic outcomes. For example, three studies have found that sustained attention is a significant predictor of maths achievement. It is also important to note that few papers use the same measures, either for attention or for academic achievement, meaning that relationships between measures of attention and academic achievement differ between studies. Furthermore, it is possible that these assessments of cognitive attention are more sensitive than behavioural ratings of attention, and therefore may be more likely to produce inconsistent findings. Studies that used both cognitive and behavioural measures of attention (Dulaney et al., 2015; Steele et al., 2012) also highlight the important issue of behavioural ratings of attention, in that they do not map on to cognitive measures of attention and that their relationship with achievement is different.

2.3.3 Autism Spectrum Disorders, attention, and academic achievement

Some studies have found that children with ASD generally perform poorly on measures of attention (Mayes & Calhoun, 2003a; Nyden et al., 1999). Factors influencing academic achievement in children with ASD are far less understood. As mentioned previously in relation to the review by Keen et al. (2016), particularly lacking in the literature is the relationship between attention and academic achievement for these individuals. Although there are a substantial number of studies investigating this relationship for TD, there are only three published papers examining the same relationships in autistic children.

Mayes and Calhoun (2007) examined several potential predictors of academic achievement with 6 to 16-year-olds across a range of groups, these being: autism, ADHD, anxiety, depression, oppositional-defiant disorder, and TD. For the purpose of this review, the focus here will be upon the findings associated with children with ASD (n = 118) and TD (n = 149) children. Although the authors do not report mean IQ scores, they do state that all participants had a Full Scale IQ (FSIQ) of 80 or above. For both samples, attention was assessed using the Vigilance and Distractibility subtests from the Gordon Diagnostic System (GDS; Gordon, 1983) which is a visual measure of attention, as well as the Digit Span subtest from the Wechsler Intelligence Scale for Children (WISC; Wechsler, 2003). For the ASD group, academic achievement was assessed using the Word Reading, Reading Comprehension, and Numerical Operations subtests of the Wechsler Individual Achievement Test (WIAT; Psychological Corporation, 1992, 2002), which provided measures of both reading and maths achievement. It is important to note that for the TD group, academic achievement was measured with Reading and Arithmetic subtests from the Wide Range Achievement Test – Third Edition (WRAT-3; Wilkinson, 1993), rather than with the WIAT, though the authors state that these two measures correlate and produce similar standardised scores. The authors also used the WISC to obtain measures of IQ, graphomotor ability and processing speed. Although they found that IQ was the strongest predictor of academic achievement in both groups, attention also made a significant contribution to the variance accounted for in both maths and reading achievement. Together, IQ, attention and graphomotor skills accounted for 34% of the variance in reading achievement (R = .59), an 8% increase over IQ alone. For maths achievement, the same predictors accounted for 49% of the variance (R = .70), an increase of 6% over IQ alone. Interestingly, they also found that the group with ASD and ADHD did not differ in performance on the attention measures (p = 1.00), and the percentage of children with impaired attention did not differ between the groups (X^2 = .20, p = .67), suggesting that the attention of individuals with ASD is comparable to those with ADHD.

May, Rinehart, Wilding and Cornish (2013) were more interested in the specific role of attention in the academic achievement of children with ASD, rather than in a range of cognitive abilities. Children ranged in age from 7 to 12 years and were diagnosed with either Autistic Disorder or Asperger’s Disorder (n = 64). Sixty TD children were also included as a comparison group. There was a significant difference in FSIQ between the two groups, with the ASD group scoring a mean of 96.78 (SD = 13.16) and the TD group a mean of 107.47 (SD = 11.57). Similar to Steele et al. (2012), the authors obtained more than one measure of attention; attentional switching (i.e. executive attention) and sustained attention. For executive attention, a visual search task was used. Children were presented with a scene on the computer screen containing trees and a river, amongst other objects, and were instructed to search for a target object, and to click on the target to reveal a monster. The target object was alternated between trials to tap the child's ability to flexibly switch their attention. To measure sustained attention, the authors used a vigilance task in which children were presented with the same display as in the previous task, but were asked to watch for a yellow border that would appear around a target shape. The children had seven seconds to click on the target. Academic achievement was measured using the WIAT-II (Psychological Corporation, 2002). The authors found that for children with ASD, whereas executive attention significantly predicted maths achievement, neither of the attention measures predicted reading achievement. This is an interesting finding, as we know that reading comprehension is a relative weakness for individuals with HFA (Troyb et al., 2014), however in this study, the authors found no significant difference in reading scores between the ASD and TD groups ($t = -1.322$, $p = .189$). In contrast, there was a significant difference in maths scores between the two groups ($t = -3.487$, $p < .001$), suggesting that this particular sample of ASD children achieved relatively high reading achievement scores. It is possible that this was due to the assessment tool used; the authors administered only the Word Reading subtest from the WIAT-II, rather than the full Reading Achievement composite, which also includes subtests of Reading Comprehension and Pseudoword Decoding. In addition, none of the attention measures predicted maths or reading achievement for the TD group, which reinforces the notion that the null relationship between attention and reading achievement may be explained by the ASD group scoring relatively high on this measure. The authors also conducted a one year follow up with the same sample (May, Rinehart, Wilding & Cornish, 2015), but found that none of the attentional measures taken at Time 1 predicted either reading or maths achievement at Time 2. The authors suggest that a year may not be a sufficiently long enough period for these associations to emerge, or that the attention tasks were not sensitive enough.

Within this limited literature there is no clear consensus regarding the role of attention as a predictor of academic achievement in children with ASD. Although one study found that attention significantly predicts academic achievement, another suggested that attention only predicts maths achievement, and a third that attention does not predict academic achievement over time. Without question, in order to strengthen our understanding of the relationship between attention and academic achievement in children with ASD, further studies are necessary. It is also important to acknowledge that in the studies described, the samples were mostly restricted to high-functioning individuals, with IQ in the typical range, rather than those with below-average IQ. It is well documented that ASD encompasses a vast spectrum of abilities and levels of functioning, therefore any research within the field of ASD should be representative of this.

2.4 Discussion

On the whole, the literature suggests that attention is related to academic achievement for TD children. A substantial number of studies using behavioural ratings of attention to predict some form of academic achievement have been relatively consistent in their findings, suggesting that children with poorer attention perform worse academically. By comparison, the review of studies that have used cognitive measures of attention suggests that the relationship between attention and academic achievement may be more complex; three studies found that measures of sustained attention significantly predicted maths achievement in children aged from 3 to 9 years, whereas three studies, including one using an ASD sample, found that executive attention was a significant predictor of reading achievement. While there is some overlap in these findings, for example, Steele et al. (2012) found that executive attention predicted both reading and maths achievement, and Razza et al. (2012) found that sustained attention predicted all academic outcomes, there appears to be a trend by which different aspects of attention are related to domain-specific skills. This theory is supported by research conducted by Wilding and Cornish (2007), who found that different aspects of performance (speed and accuracy) in visual search and sustained attention tasks reflected different attentional mechanisms. It is clear that to understand the relationship between attentional processes and the types of academic outcomes these are related to, further research is imperative; nevertheless, the findings of this narrative review give an important insight into the mechanisms that may influence maths and reading achievement for children.

It is also important to consider whether these relationships may be different for children with ASD. Findings by Mayes and Calhoun (2007) concurred with the TD literature in that reading achievement was predicted by executive attention, however they also found this attentional process was important for maths achievement. Furthermore, contrary to the TD literature, May et al. (2013) found no relationship between sustained attention and reading or maths achievement, but instead that executive attention concurrently, but not longitudinally, predicted maths achievement. Although these findings suggest that the relationship between attentional processes and academic outcomes may be different for children with ASD, differences in the age groups tested and the limited number of papers make it difficult to generalise the findings.

Based on the findings of this narrative review, a recommendation is that future research investigating the relationship between attention and academic achievement focuses on measures that tap distinct attentional processes, and consider how these may relate to maths and reading achievement independently. In addition, researchers and clinicians who have a broader interest in attention, over and above its relation to academic achievement, should carefully consider their choice of measurement; while observer ratings of attention are a relatively robust, time- and cost-effective measure of overt attentional behaviour, if researchers and clinicians wish to understand specific attention abilities in children, performance based cognitive measures should instead be utilized. Furthermore, it is important to acknowledge that the papers reviewed here all consider the relationship between attention and academic achievement based on independent measurements of these abilities. Although it is vital to first understand how these two underlying elements of child development are related, a sensible direction of future research would be to investigate whether time on task is related to performance on the same task. One example of such work is that of Hanley et al. (2017), as described in Chapter One, who used eye-tracking techniques and video based lessons to explore how classroom visual displays impacted attention and learning for children with and without an ASD. The authors found that the presence of displays had an impact on learning, in that all children performed worse when visual displays were present, but that this effect was stronger for children with ASD. Furthermore, they found that attention to the visual background significantly predicted learning, which suggests that the more time children spent looking at the background, the poorer their learning outcomes were. This suggests that time on task (i.e. in this instance, time spent looking at the teacher) may be important for learning, for children with and without ASD. This will be returned to in Chapter Four.

The literature review in this chapter has highlighted some important considerations in relation to investigating the relationship between attention and academic achievement, for children both with and without ASD. First, the inconsistency with which attention is rated and/or measured is particularly noteworthy. Although the majority of studies in this field focus upon behavioural ratings of attention, very few use the same standardised assessment, and some use measures that may not be appropriate for predicting academic achievement. The literature seems to concur that higher ratings of behavioural inattention are related to poorer academic achievement, however it is difficult to determine the reliability of the conclusions due to the inconsistency with which attention has been measured. Moreover, despite the focus of existing research on behavioural ratings of attention, very few studies have addressed the relationship between cognitive attention and academic achievement, and similarly the measures and findings are inconsistent between studies. Further investigation of the relationship between cognitive attention and academic achievement is therefore required.

Furthermore, it is strikingly clear that more research is necessary to investigate this relationship for individuals with ASD. Not only is research on this topic limited, but conflicting, making it even more pressing that this relationship is examined. Investigating attention in ASD is, however, methodologically complex, as Ames and Fletcher-Watson (2010) have reported. The ways in which researchers have attempted to measure what they all define as "attention" varies widely, whether this be through cueing paradigms, eye-movement tracking in scene viewing, or change detection paradigms. Ames and Fletcher-Watson (2010) argue that the variation in findings on the topic of atypical attention in ASD could be attributable to this methodological inconsistency and ambiguity.

Finally, it is vital to also consider the samples used within this research. Not only within this area, but within the ASD research field as a whole, samples are generally restricted to higher functioning individuals, with very little representation of individuals with more severe autism and below-average IQ. Based on the findings of Keen et al. (2016) regarding predictors of academic achievement, it is highly likely that the relationship between attention and academic achievement varies between individuals. It is therefore vital that individuals across the width of the autism spectrum are represented, rather than maintaining a focus on high functioning individuals. Assessments and/or tasks designed for TD individuals are arguably not suitable for participants with severe autism, particularly if they have poor or no verbal communication. One recommendation is therefore that assessments are designed to enable these abilities to be measured inclusively. Tager-Flusberg et al. (2016) have provided valuable recommendations for conducting research with minimally verbal individuals with ASD. Although this was focused more upon the administration of assessments and attitudes towards research with this group, rather than on adapting assessments to make them accessible, their commentary on conducting inclusive ASD research is a valuable and welcomed addition to the literature.

This review highlights a substantial discrepancy in the literature between research with TD and autistic populations, and it is vital to close this gap. It is also imperative that researchers draw upon the existing literature when making methodological decisions. As outlined earlier in the case of the TD literature, it is difficult to draw conclusions from a body of studies where the methods of measuring attention and academic achievement are inconsistent. It is therefore important that future studies use comparable measures of academic achievement, and that they are able to define the form of attention that they are measuring more concisely. In order to do this, however, appropriate measures of both attention and achievement for individuals with ASD must be recognised. The following chapters of this thesis aim to address some of these issues.

Chapter Three: The role of attention in profiles of academic achievement

The first two chapters of this thesis have provided a detailed background on the literature relating to attention and learning in typical development and autism. Chapter Two emphasised the importance of further research into this relationship in autism, due to the limits and scarcity of existing published studies. Also highlighted in previous chapters was the importance of understanding attention as a multi-computational function, as sustained, selective and executive attention are independent and have different developmental trajectories in typical development (Lewis et al., 2018; Steele et al., 2012). The purpose of this chapter is not only to understand the attentional profile of children with an ASD, but also to recognise the implications of this for other aspects of functioning, such as academic achievement.

3.1 Introduction

Chapter Two outlined the existing literature that has considered attention as a predictor of academic achievement. This review found that measures of observed attention behaviours, as rated either by parents or teachers, are predictive of academic achievement for TD children both concurrently (e.g. Pham, 2016; Sarver et al., 2012) and longitudinally (e.g. Breslau et al, 2009; Duncan et al., 2007; Fleming et al., 2005; McClelland et al., 2013). Children who are observed to be more attentive generally perform better in academic domains, such as reading and maths, than children who are inattentive. Despite these findings, research regarding cognitive measures of attention and their concurrent and longitudinal relationships with academic outcomes is minimal and has mixed findings. The relationship between attention and academic achievement for children with an ASD is far less understood than for TD children. Both Mayes and Calhoun (2007) and May et al. (2013) found evidence that attention is important for academic achievement, but due to the differences in measures of attention, their findings were not entirely consistent. Considering that children with ASD have been found to have discrepancies in the different aspects of reading and maths abilities (Chen et al., 2019; Miller et al., 2016; Kim, Bal & Lord, 2018), it is important to obtain a full assessment of the wider reading and maths abilities of these children, rather than measure their academic achievement using single subtests (that might touch on pockets of strength or weakness).

3.1.1 Profiles of achievement in ASD

Academic outcomes of individuals with an ASD vary a great deal (Keen, Webster, & Ridley, 2016), and investigating why and in what context this variance exists could inform how individuals with an ASD are best supported in school. Keen et al.'s (2016) review demonstrated the importance of considering within-group differences for individuals with ASD, rather than focusing only at the group level. Discrepancies between the sub-components of both reading and maths achievement were identified, which is an important finding in relation to understanding learning in autism.

Discrepancies between basic word reading and reading comprehension have been observed in a number of studies (Huemer & Mann, 2010; Jones et al., 2009; Kim et al., 2018; Nation, Clarke, Wright, & Williams, 2006), suggesting that the ability to infer meaning from text passages may be a difficulty for this developmental group, even when their word recognition is typical; for these children, it was therefore the more cognitively demanding tasks that were more difficult. Jones et al. (2009) found that the deficit in reading comprehension was related to the severity of social and communication problems, as measured by the Social Responsiveness Scale. By comparison, Nation et al., (2006) found that children with an ASD who had poor reading comprehension also had poor non-word decoding skills and suggested that decoding skills could be one of the factors in reading comprehension deficits. However other studies have found decoding skills to be typical in children with ASD (Huemer & Mann, 2010), suggesting that there may be other factors underlying reading comprehension in this group. Given that cognitive factors such as attention skills are strong predictors of academic achievement in TD children (e.g. Duncan et al., 2007), it is quite possible that the ability to understand the meaning of a passage may also be related to cognitive factors. If the factors that influence this ability in children with an ASD can be identified, this may inform the development of interventions to identify and support children with this particular difficulty.

There is mixed evidence regarding maths ability in children with an ASD. While a number of studies have found that children with an ASD have less proficient maths ability than TD children (Jones et al., 2009; Estes et al., 2011, Troyb et al., 2014), others have found that their maths ability is comparable to or better than TD children (Brosnan et al., 2016; Iuculano et al., 2014; Titeca et al., 2015). Keen et al. (2016) found that mean maths performance was generally within the average or below-average range, although this was highly variable at the individual level. It is possible that discrepancies between different mathematical skills exist, as with the reading discrepancies described above. For example, Miller et al. (2016) found that children with ASD scored lower on a measure of mathematical reasoning, compared to their numerical operations score, although this difference wasn't found to reach significance. In addition, Wei et al. (2015) found that a subgroup of children who had been defined as 'low-achieving' (i.e. scored 2 standard deviations below national average on achievement measures) scored worse on an applied problems task (i.e. maths reasoning) than on a calculation task. Although these studies do not provide clear evidence for a discrepancy between different aspects of mathematics skills in children with an ASD, they do indicate that there may be reasons to investigate this further. As with reading achievement, it is also important to investigate the factors that may underlie the discrepancies or performance across different aspects of maths skill. As the previous chapters have highlighted, attention is important for learning and has been found to predict academic achievement. With this in mind, it may be the case that attention abilities play a role in defining these different profiles of achievement.

3.1.2 Current study

The first aim of the current study was to use standardised measures of attention and academic achievement to investigate the reading and maths achievement profiles for children with an ASD, and to determine whether attention skills play a role in characterising these profiles. Based on the multi-computational model of attention, sustained, selective, and executive attention were the three theory derived attentional processes of interest; these are the most widely researched subtypes of attention in this field and are generally considered to have different developmental trajectories in typical development (Steele et al., 2012). It was important to use a standardised measure of attention that provided scores for these subtypes of attention, but also that had been previously used in an atypically developing group. The Test of Everyday Attention for Children (TEA-Ch; Manly, Robertson, Anderson, & Nimmo-Smith, 1999) has previously been used with autistic children (Harper-Hill, Copland & Arnott, 2014; Henry et al., 2017; Kenworthy, Black, Harrison, Rosa & Wallace, 2009; Pasiali, LeGasse, & Penn, 2014), therefore it was considered to be suitable for use with the current sample. The TEA-Ch provides subtests for individual attentional processes, which include sustained, selective and divided attention. Executive attention is a higher-order attentional process and encompasses a range of abilities such as dividing attention, attention switching, or conflict resolution, therefore few tasks can claim to measure a "pure" form of executive attention. Steele et al. (2012) raised this important issue of task specificity in their study of 3 to 6-year-old TD children, arguing that the type of executive attention recruited by their spatial conflict task was "early emerging" compared to other types of executive attention (p. 2038; Steele et al., 2012). With this in mind, although various sub-tests tapping executive attention exist within the TEA-Ch, the divided attention task was chosen as it reflects the division of attention between auditory and visual domains that children experience while learning in the classroom (e.g. listening to the teacher while looking at their work) and is therefore relevant for an investigation of learning. Divided attention has been found to be atypical in both adults and children with autism (e.g. Boxhoorn et al., 2018; Casey, Gordon, Mannheim & Rumsey, 1993), reflecting similar findings in the literature regarding atypicalities in executive attention. Kenworthy et al. (2009) also found that auditory divided attention performance was related to autism symptoms, in that children with poorer divided attention had more severe symptoms of autism related to social and communication difficulties, but not RRBs. This reinforces the notion that divided attention ability may be atypical in autism.

To measure reading and maths achievement, the WIAT-II was chosen for two reasons. First, this measure has been used previously with children with an ASD (Mayes and Calhoun, 2007; May et al., 2013, 2015), therefore it is appropriate for use with a similar sample. Secondly, it provides composite scores of academic outcomes that are calculated based on two (maths) or three (reading) subtests and this therefore allows an in-depth examination of abilities both within (by comparing performance on subtests within each composite) and between academic domains. Importantly, previous research on this topic has only used individual subtests of the WIAT-II as measures of reading and maths achievement, which do not provide a full assessment of ability within these domains of interest, as previously mentioned. Using the full composites for both academic domains was therefore important in this study.

The first aim was to be achieved by investigating the specific attentional processes that were related to reading and maths achievement. A subsequent aim was to use these findings to study subgroups of children with ASD based on the attention skills that were important for academic achievement, to examine in detail whether different profiles of achievement are characterised by different attention skills. To examine the profiles of these subgroups, the different components of reading achievement (word reading, phonetic decoding, and reading comprehension) and maths achievement (numerical operations and mathematical reasoning) were compared both within and between subgroups.

Due to the limited existing literature, it was difficult to make predictions for all of the attention measures. Research suggests that sustained attention is a longitudinal predictor of achievement in TD children (Steele et al., 2012; Razza et al., 2012), and further to this, research suggests that children with an ASD perform typically on sustained attention tasks. It was therefore predicted that sustained attention would not be concurrently related to reading or maths achievement for children with an ASD.

To date, the relationship between selective attention and academic achievement in children with an ASD has not been reported, therefore the investigations related to this measure were exploratory. There is, however, research to suggest that higher order executive attention skills (such as attention switching) are predictive of maths achievement in ASD (May et al., 2013), therefore it was predicted that the divided attention measure would be related to maths achievement. As the literature has shown that attention is predictive of academic achievement, it was expected that different profiles of achievement would emerge between subgroups of children with ASD based on their attention scores. More specifically, children with below group average attention skills would have more distinct discrepancies between the different aspects of reading and maths achievement compared to children with above group average attention skills.

The existing literature acknowledges the heterogeneity of academic achievement in ASD (e.g. Keen et al., 2016; Kim et al., 2018), but does not consider where individuals with ASD lie when looking transdiagnostically (i.e. alongside TD individuals). It is important to consider whether or not these profiles are unique to ASD, therefore the profiles of attention and achievement more broadly across TD children and children with ASD were investigated using cluster analysis. The purpose of this was to discover meaningful subgroups based on achievement and attention abilities that may exist within the ASD population, but also look transdiagnostically (i.e. both TD and ASD) to examine the variance within the sample as a whole, and to understand where children with ASD fall. This analysis was exploratory, however distinct subgroups were expected to emerge that were not solely driven by ASD diagnosis, due to the heterogeneous nature of this population and of attention skills in both typical development and ASD.

3.2 Method

3.2.1 Participants

The sample consisted of 59 TD children (32 males), ranging in age from 6 years and 4 months to 11 years and 3 months (*M* = 108.02 months, *SD* = 14.58), and 27 children with ASD (22 males), ranging in age from 6 years and 1 month to 16 years (*M* = 129.56 months, *SD* = 35.73). Previous studies of attention in typical development have focused on pre-school age children, whereas studies of children with ASD have focused on primary and secondary school ages. In this study it was deemed important to focus on similar ASD groups to the extant literature, and therefore it followed to include TD children who were of a similar age. The age range of children with an ASD is larger, due to the heterogeneity of cognitive ability, not related to age, that is seen in this sample. Typically developing children with a similar cognitive ability range were included. Children with ASD with genetic disorders or a diagnosis of ADHD were not eligible to participate. This information was collected via parent report. TD children were recruited from mainstream schools or through local contacts, while children with ASD were recruited from i) mainstream schools with SEN provision, ii) SEN or ASD specialised schools, iii) the Autism Spectrum Disorder-UK database (ASD-UK), and iv) local contacts. Parents provided informed consent and children provided assent prior to taking part.

3.2.2 Materials

Participants completed a battery of standardised assessments measuring performance on a range of cognitive tasks, providing scores of full-scale IQ, as well as their level of academic achievement in reading and mathematics, and tasks that measured selective, sustained and divided attention.

3.2.2.1 Measures of attention

Three measures of attention were obtained using subtests of the Test of Everyday Attention for Children (TEA-Ch; Manly et al., 1999), which is suitable for children aged 6 to 16 years. Scores on each subtest were standardised based on age and gender. Scaled scores within one standard deviation (*SD* = 3) of 10 indicated performance in the normal range (12^{th} to 87^{th} percentiles). The authors report that test-retest reliability for each subtest is good (all *r*'s > .7).

To measure selective attention, children completed the Sky Search subtest, in which they were presented with an A3 visual array containing images of pairs of spaceships, which were either matching or odd pairs. Children were asked to circle each matching pair as quickly as they could while trying to not miss any. Twenty targets (matching pairs) were present among 108 distractors (odd pairs). Children also completed a motor control version of the task, to account for differences in motor speed. In this version of the task, no distractors were present and children were timed while they circled the matching pairs. The overall time taken and number of targets correctly identified were used to determine a "time-per-target" score, from which the motor control time-per-target score was removed.

To measure sustained attention, the "Score!" subtest was administered. This involved a 10-trial counting task in which the subject listened to a series of identical tones, between 9 and 15 tones per trial, and was asked to state at the end of each trial how many tones they heard. Each trial consisted of identical tones of 345ms played intermittently with intervals of between 500 and 5000ms. Children were asked to count silently, without the use of their fingers. The number of correct trials was used as a measure of ability to sustain attention over time.

The Sky Search DT subtest was used to assess divided attention. This assessment combines the Sky Search and Score! subtests, making this a dual task, as participants must complete both tasks at the same time. Children were asked to complete a version of the Sky Search, identical to the task they had already completed, except with targets in different locations. They were simultaneously presented with tones identical to those used in the Score!

subtest, presented in intervals of one tone per second. The test ended once the child had indicated that they had completed the visual search task. To obtain an overall score for divided attention, scores from both dual task components, and from the single task Sky Search were used. The dual task Sky Search time-per-target score was divided by the proportion of counting items correct (total items correct/total items attempted), and the raw time-per-target from the single task Sky Search was then subtracted from this value. This provided a divided attention score based on the discrepancy between single-task and dual-task visual search performance.

3.2.2.2 Measures of academic achievement

Measures of reading and maths achievement were obtained using the Wechsler Individual Achievement Test, Second Edition (WIAT-II; Wechsler, 2005), which is appropriate for children aged from 4 years to 16 years 11 months. The WIAT-II has strong inter-item consistency within subtests (Cronbach's alpha < .8), and has good test-retest reliability (all *r's* < .85). As with most standardised assessments, subtests each increase with difficulty, therefore they have start points based on age group, as well as rules for discontinuing (e.g. after a certain number of incorrect answers) and reverse administering (e.g. if a participant provides incorrect responses for the first three items). The reading achievement composite score was calculated using scores on three sub-tests: Word Reading, Pseudoword Decoding, and Reading Comprehension. In the Word Reading subtest, participants aged 8 and above are presented with an A4 card with a list of words and are asked to read each word out loud. The participant receives a mark of one for correctly read words, and zero for words read incorrectly. This continues until they receive seven scores of zero in a row. For children under eight, the subtest begins with an assessment of letter recognition, phonological awareness, and sound-symbol relationships. The Pseudoword Decoding subtest requires participants to read non-words from a list, measuring their ability to correctly pronounce words based on their phonetic structure. The Reading Comprehension subtest requires participants to read passages of text and answer questions based on these passages, measuring their understanding of the passages within context. The reading achievement measure therefore encompasses not only basic word reading ability, but also phonetic decoding and the ability to read text passages and understand their context.

The maths achievement composite score was calculated based on two subtest scores: Numerical Operations and Mathematical Reasoning. The Numerical Operations subtest is a workbook based task, in which participants are presented with maths problems increasing in difficulty and must write their answers on the worksheet. Problems start with basic numerical knowledge (e.g. counting to 10) and advance through addition, subtraction, multiplication, division, and on to more advanced problems such as algebra. The Mathematical Reasoning subtest measures a participant's ability to apply mathematical problem solving to contexts, for example, presenting them with problems related to time, money or measurement. These problems are presented one at a time on a flipbook, and participants are required to give their answer verbally. They are given paper for working out their answer if needed. Together, these subtests provide a maths measure that comprises the ability to count and calculate, with mathematical problem solving in context.

3.2.2.3 Cognitive ability

The Wechsler Abbreviated Scale of Intelligence, Second Edition (WASI-II; Wechsler, 2011), suitable for individuals aged from 6 to 90 years, was used to obtain an estimate of full-scale intelligence (FSIQ-4) for all children. This is an abbreviated measure of intelligence that includes four subtests (block design, vocabulary, matrix reasoning, similarities) that together measure vocabulary and non-verbal reasoning. This abbreviated version was chosen due to the extensive battery of tasks that children were being asked to complete. The FSIQ-4 scores from this measure correlates with the Wechsler Intelligence Scale for Children – Fifth Addition (WISC-V; Wechsler, 2014), r = .87 (Raiford, Zhou, & Drozdick, 2016). This measure has been used extensively with children with an ASD (e.g. Kim et al, 2017; Mayes & Calhoun, 2007; McIntyre et al., 2017; Troyb et al., 2014). All scores were age standardised.

3.2.3 Procedure

Testing was conducted individually either in a quiet room at the child's school, their home, or at the university. Testing occurred across four sessions, each lasting approximately 30 minutes to meet the needs and attentional demands of all participants. Participants completed the WASI-II, followed by the WIAT-II and the TEA-Ch. Testing sessions took place on different days, to ensure that children remained focused for the duration of each assessment. The number of days between each session varied, depending on the availability of the participant, but all children completed the assessment battery within a three-week period.

3.3 Results

Within-group analyses were conducted using age standardised scores for each measure, therefore age differences were already accounted for in the analyses. This was important due to the wide age range of children within the sample, allowing children to be examined based on their cognitive ability relative to their chronological age, as opposed to comparing across age groups.

3.3.1 Descriptive statistics and correlations

3.3.1.1 Group profiles

As a group, on average TD children performed as expected based on chronological age across the majority of measures (Table 3.1). Furthermore, their reading achievement, maths achievement, and FSIQ standardised scores all fell within the normal range (i.e. 70-130). Sustained attention group performance was average, as would be expected for TD children, however their selective and divided attention scores were slightly below average, though still within one standard deviation of the norm.

When comparing between groups, children with an ASD were significantly older than the TD children (Table 3.1), with a wider age range. In terms of cognitive and academic performance, children with ASD scored lower on almost all measures; they had lower IQ, and poorer reading and maths achievement, although performance was still within one standard deviation of age norms for reading.

With regards to attention skills, TD children had higher selective and divided attention scores than children with an ASD (Table 3.1), however the groups did not differ on sustained attention performance. Five children with ASD (18%) could not complete the divided attention subtest, and four of these children could also not complete the sustained attention subtest (15%). Non-completion was attributed to difficulties understanding the instructions, or task requirements. In the final sample there were therefore complete data sets for 22 children with ASD.

3.3.1.2 Correlational analyses

Two-tailed correlations were conducted exploring at the relationships between the standardised measures, and the results for TD children are presented in Table 3.2. For TD children, IQ was significantly positively related to both reading achievement and maths achievement but was not significantly related to any of the attention measures. In terms of attention and achievement, selective attention and divided attention were not correlated with either of the achievement measures, although the relationship between divided attention and

Table 3.1. Descriptive statistics for cognitive measures

	TD children (N = 59)				Children with ASD (N = 27)				Group differences
	M	SD	Min	Max	M	SD	Min	Max	*t*
Age in months	108.02	14.58	83	135	129.56	35.73	73	192	-4.14***
FSIQ-4	98.28	12.07	75	129	89.41	15.81	59	127	2.84**
Reading achievement	102.74	12.66	71	132	87.37	20.75	43	148	4.21***
Maths achievement	104.36	15.76	74	145	80.26	24.21	41	142	5.59***
Selective attention	6.95	2.51	1	12	5.44	2.97	1	11	2.39*
Sustained attention	9.07	3.27	2	15	8[a]	3.46[a]	1	15	1.31
Divided attention	7.36	3.68	1	15	3.95[b]	4.28[b]	1	17	3.53***

* p < .05, ** p < .01, *** p < .001; [a] N = 23; [b] N = 22

Table 3.2. Correlation matrix for TD sample (N = 59)

	1	2	3	4	5
1. FSIQ					
2. Reading achievement	.510***◊				
3. Maths achievement	.609***◊	-.647***◊			
4. Selective attention	.089	-.099	.063		
5. Sustained attention	.106	.216	.199	-.187	
6. Divided attention	.213	.212	.003	-.088	.092

*** p < .001, ◊ significant effect after Bonferroni correction

reading approached significance, $r(59) = .212$, $p = .053$. Sustained attention was significantly positively related to reading, but not maths.

For autistic children (Table 3.3), IQ was related to reading achievement and maths achievement. Similar to the TD sample, IQ was not significantly related to either selective or sustained attention, however by contrast it was positively related to divided attention. Divided attention was significantly related to both reading achievement and maths achievement, in that children with better divided attention ability had higher reading andmaths scores. As maths, reading and divided attention were all significantly correlated with IQ, there was a possibility that IQ was driving these relationships, therefore the correlations were re-run while controlling for IQ. The relationship between divided attention and maths achievement remained significant, $r(19) = .589$, $p = .005$, however the relationship between divided attention and reading achievement was no longer significant, r(19) = .320, $p = .158$. Selective and sustained attention were not related to the achievement measures.

3.3.2 Sub-components of reading and maths achievement for children with an ASD

Given the heterogeneity of divided attention in the ASD group and its significant correlation with both achievement measures, a comparison of those who performed within the normal range to those who found the task particularly difficult was conducted. The sample was therefore split into two groups: those who could not complete the divided attention measure or scored 1 ("poorer divided attention"; N = 17), and those who scored above 1 ("better divided attention"; N = 10). Divided attention scores for children in the "better divided attention" subgroup ranged from 3 to 17 ($M = 7.5$, $SD = 4.14$). Children in

Table 3.3. Correlation matrix for ASD sample (N = 27)

	1	2	3	4	5
1. FSIQ					
2. Reading achievement	.744***◊				
3. Maths achievement	.781***◊	.787***◊			
4. Selective attention	.175	.114	.244		
5. Sustained attention [a]	.329	.283	.295	.322	
6. Divided attention [b]	.537*	.591**◊	.729***◊	.461	.221

*p <.05, ** p <.01, *** p < .001; [a] N = 23; [b] N = 22, ◊ significant effect after Bonferroni correction

the "poorer divided attention" subgroup had slightly lower FSIQ (*M* = 85.18, *SD* = 15.26) than children in the "better divided attention" subgroup (*M* = 96.6, *SD* = 14.71), though this difference was not statistically significant, $t(25) = -1.9$, $p = .07$, $d = 0.76$.

Discrepancies between the sub-components of achievement have previously been observed in children with ASD, therefore these different components of reading achievement (word reading, pseudoword decoding and reading comprehension) and maths achievement (numerical operations and mathematical reasoning) were analysed. It was possible to consider how the independent components of reading and maths achievement may be related to attention by looking within and between the attentionally-determined subgroups of ASD children described above.

3.3.2.1 Word reading vs. reading comprehension in attentional subgroups of ASD

Scores on word reading, pseudoword decoding and reading comprehension were compared (Figure 3.1) and differences were analysed using independent t-tests. All children achieved higher word reading scores compared to their reading comprehension scores. Word reading scores were not significantly different between the two subgroups, $t(25) = 1.44$, $p = .164$, $d = .55$, however children with "poorer" divided attention had significantly lower reading comprehension scores (*M* = 77.65, *SD* = 15.66) than children with "better" divided attention (*M* = 94.3, *SD* = 21.8), $t(25) = -2.31$, $p = .03$, $d = 0.87$, with a large effect size. Further to this, children with "poorer" divided attention had significantly lower reading comprehension scores (*M* = 77.65, *SD* = 15.66) compared to their word reading (*M* = 87, *SD* = 17.56), $t(16) = -4.14$,

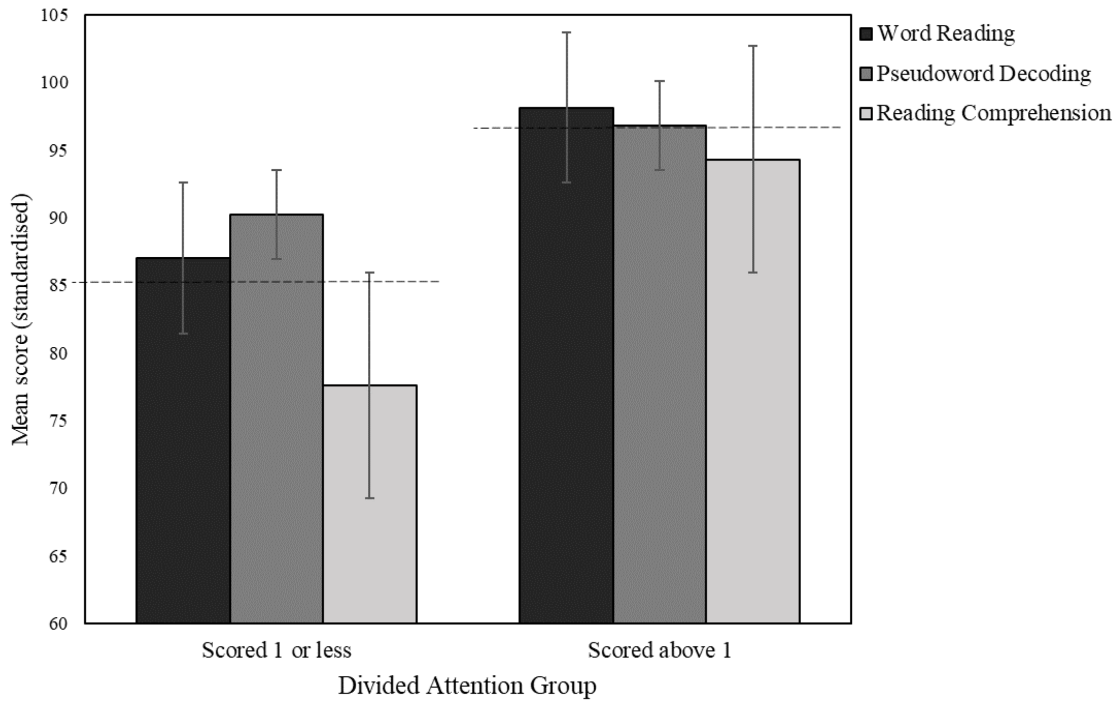

Figure 3.1. Comparison of word reading, pseudoword decoding and reading comprehension scores for children with an ASD, based on level of divided attention ability. Dotted line indicates group mean FSIQ.

p =.001, d = .56. By comparison, for the children with "better" divided attention, there was no significant difference between their word reading and reading comprehension performance, $t(9) = 1.49$, $p = .170$, $d = .17$.

With regards to pseudoword decoding ability, scores on this measure did not differ significantly between the two subgroups, $t(25) = .97$, $p = .343$, $d = .37$. For children with "poorer" divided attention, word reading and pseudoword decoding ($M = 90.24$, $SD = 15.62$) scores did not differ from one another, $t(16) = 1.2$, $p = .25$, $d = .19$, suggesting their skills in both of these tasks were equivalent. However, their mean reading comprehension score was significantly lower than pseudoword decoding, $t(16) = 5.25$, $p < .001$, $d = .8$, which corresponds with the pattern observed when comparing word reading ability to reading comprehension. For children with "better" divided attention, there was no difference between word reading and pseudoword decoding, $t(9) = .51$, $p = .625$, $d = .06$, or between pseudoword decoding and reading comprehension, $t(9) = .64$, $p = .536$, $d = .12$.

3.3.2.2 Numerical operations vs. mathematical reasoning in attentional subgroups of ASD

Scores for numerical operations and mathematical reasoning were compared (Figure 3.2) and analysed using t-tests. Children with "better" divided attention performed better on

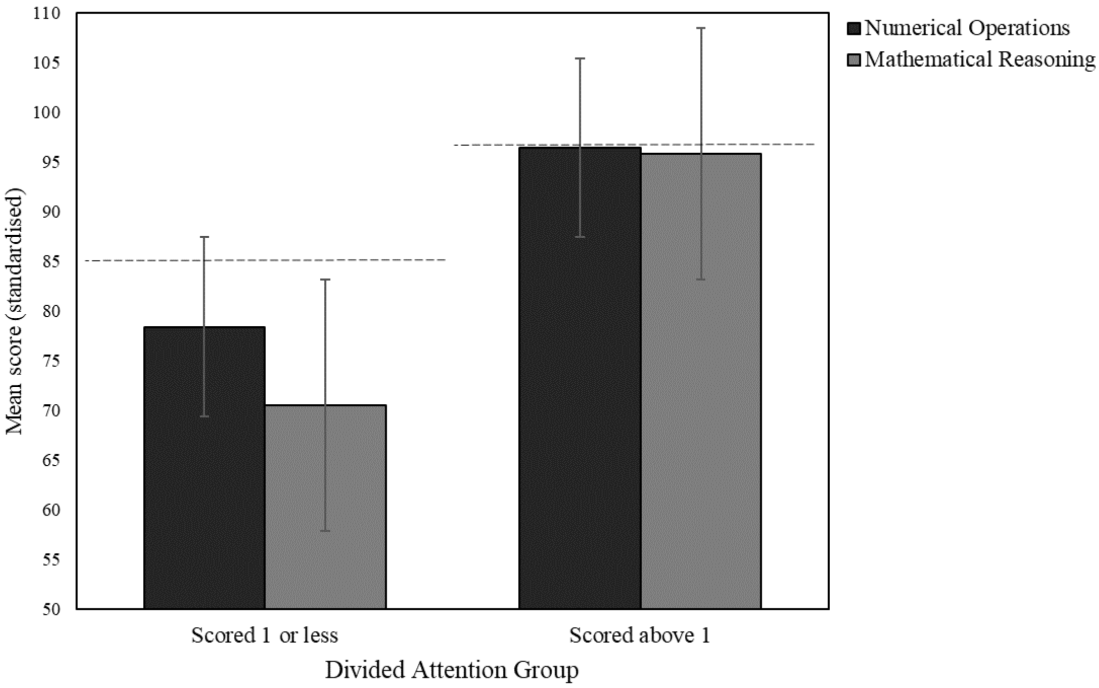

Figure 3.2. Comparison of numerical operations and mathematical reasoning scores for children with an ASD, based on level of divided attention ability. Dotted line indicates group mean FSIQ.

both maths tasks than children with "poorer" divided attention (numerical operations, $t(25) = 2.4$, $p = .024$, $d = .91$; mathematical reasoning, $t(25) = 3.03$, $p = .006$, $d = 1.17$), suggesting that their maths ability overall was superior. In terms of discrepancies between the two aspects of maths ability, children who had "better" divided attention scored similarly on both numerical operations ($M = 96.4$, $SD = 22.77$) and mathematical reasoning ($M = 95.8$, $SD = 24.33$), $t(9) = .13$, $p = .899$, $d = .03$. However, children with "poorer" divided attention scored significantly worse on mathematical reasoning ($M = 70.47$, $SD = 18.9$) than numerical operations ($M = 78.35$, $SD = 16.21$), $t(16) = 2.35$, $p = .032$, $d = .45$, suggesting that a discrepancy between calculation and reasoning ability existed in this group.

3.3.3 Transdiagnostic clustering

Having considered the academic profiles of autistic children based on their divided attention abilities, another aim of this study was to look transdiagnostically (i.e. both TD and ASD) to investigate whether meaningful subgroups emerged based on achievement and attention abilities. Due to the vast heterogeneity of ability within the ASD population, it was important to examine the variance within the whole sample, and to consider where children with an ASD fall within this sample.

Table 3.4. Means and standard deviations for IQ, achievement, and attention for each profile

	A: Good attention higher achieving (N = 5)	B: Average attention, average achieving (N = 57)	C: Poor attention, lower achieving (N = 19)
	M (SD)	M (SD)	M (SD)
FSIQ-4	120.8 (6.65)	97.49 (10.48)	86.42 (12.09)
Reading	128.4 (12.3)	102.09 (11.17)	81.42 (13.36)
Maths	136.4 (7.47)	103.53 (13.14)	73.42 (16.04)
Divided attention	13.4 (2.7)	7.42 (3.16)	1.63 (1.38)

3.3.3.1 Hierarchical cluster analysis

As previous analyses showed that divided attention was significantly related to reading and maths achievement for children with ASD, and further analyses revealed that divided attention may be of importance, this measure of attention was entered into the cluster analysis, alongside reading and maths achievement. All children who completed the divided attention measure (i.e. both TD and ASD samples) were included in the analysis (N = 81). Hierarchical cluster analysis was used to identify profiles of children according to their reading, maths and divided attention scores. This method of analysis combines cases into homogenous clusters in sequential steps; at each step, the squared Euclidean distance between two cases or clusters is compared, and cases or clusters with the smallest distance are merged into a single cluster. Average-linkage criterion was used, therefore that at each step, the distance between every case in the first cluster and every case in the second cluster was calculated and averaged, before being compared to one another.

A three-cluster solution was determined, and the means and standard deviations of achievement, divided attention and IQ for each cluster are shown in Table 3.4. Profiles A, B and C characterised 6.2%, 70.4% and 23.5% of the sample, respectively. The “good-attention-higher-achieving” profile (A) characterised children whose intelligence, reading achievement and divided attention scores were 1 SD above the national average, and whose maths achievement was 2 SDs above the national average. The “average-attention-average-achieving” profile (B) characterised children whose intelligence, reading and maths achievement scores were at the national average. Their divided attention was slightly below average, but still within 1 SD. The "poor-attention-lower-achieving" profile (C) characterised children whose reading achievement was 1 SD below the national average, and maths achievement was almost 2 SDs below average.

In terms of ratio between TD and ASD children in each profile, ASD children comprised 20% of the "good-attention-high-achievers" (N = 1), 10.5% of the "average-attention-average-achievers" (N = 6), and 78.9% of the "poor-attention-low-achievers" (N = 15). Children with ASD were therefore present in all profile groups, but were more dominant in the "poor-attention-low-achievers" group. This emphasises the heterogeneity in attention and achievement between children with ASD, and the importance of looking at performance and ability in these areas transdiagnostically.

3.3.3.2 Within-cluster achievement profiles

Also of interest were the achievement profiles within these three distinct sub-groups of children, which are presented in Figure 3.3. First, the differences between reading and maths achievement within each group were considered. For profiles A and B, reading and maths achievement scores did not differ (A: t (4) = 2.2, p = .09, d = .79; B: t (56) = .83, p = .41, d = .12). For profile C, maths achievement was significantly lower than reading achievement, t (18) = 2.71, p = .01, d = .54. To investigate this further, the deviance of maths achievement from IQ was examined. The purpose of this was to determine whether maths achievement scores were different from what should be expected based on intelligence, and whether this varied between profile groups. Figure 3.4 displays the mean deviance of maths achievement score from FSIQ score, for each profile group. For each group, maths achievement significantly deviated from what we would expect based on FSIQ. For the "good-attention-high-achievers", their mean maths achievement was significantly higher than their mean FSIQ score, t (4) = 4.25, p = .013, d = 2.21, and this pattern was the same for the "average-attention-average-achievers", t (56) = 3.61, p = .001, d = .51. However, for the "poor-attention-low-achievers" group, there was a significant discrepancy, in that the mean maths achievement was much lower than the mean FSIQ, t (18) = -4.51, p < .001, d = .92.

3.4 Discussion

3.4.1 Attentional characteristics of children with ASD

Sustained attention performance was similar across TD and ASD samples, which supports previous findings that sustained attention ability is more typical in autistic children than other components of attention (Garretson et al., 1990; May et al, 2013, Pascualvaca et

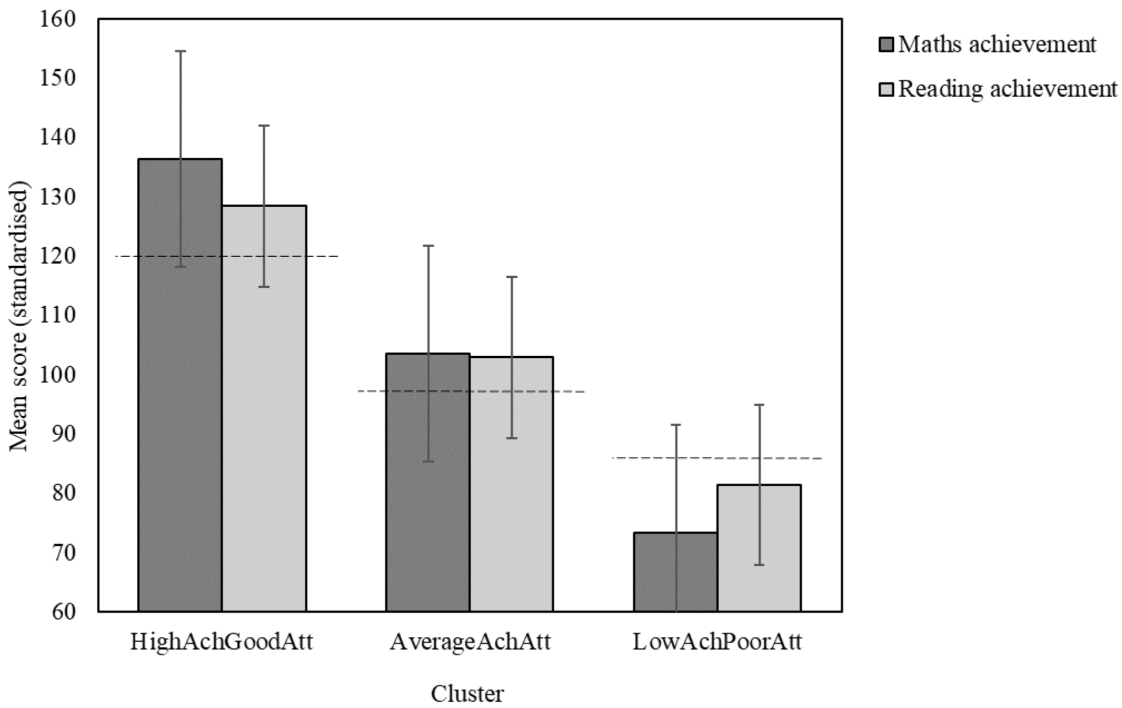

Figure 3.3. Maths and reading achievement scores for each cluster. Dotted line indicates group mean FSIQ.

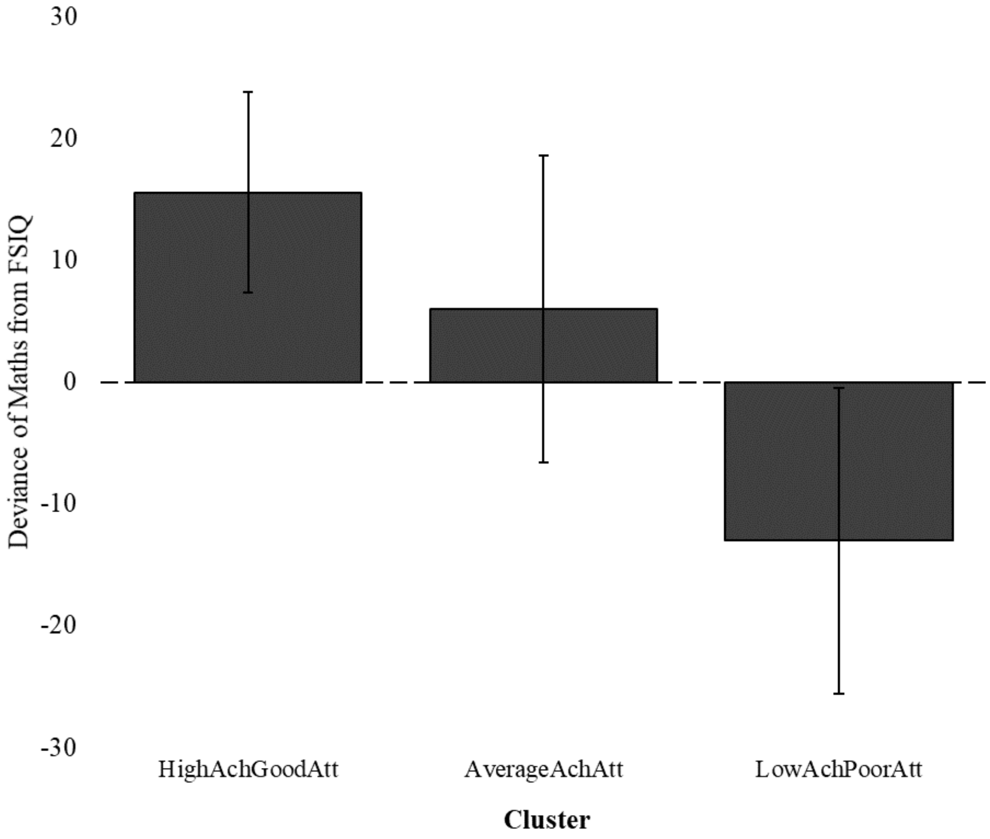

Figure 3.4. Deviance of maths achievement scores from IQ for each cluster. Dotted line indicates group mean FSIQ.

al, 1998). However, when comparing selective attention and divided attention between TD and ASD samples, children with an ASD scored lower on average than TD children across both measures. Research has previously found that selective attention is atypical in autistic children (Burack, 1994; Dawson et al., 1998; Renner et al,. 2006), and the current findings support this notion, suggesting that children with an ASD may find it difficult to select the appropriate information required for a particular task or situation. Similarly, studies have found divided attention to be atypical in children with an ASD (Boxhoorn et al., 2018) and the current findings concur. As this divided attention task recruits a higher-order attentional component to manage attention across two modalities, arguably this reflects executive attention ability, which has also been found to be atypical in autistic children (Mayes & Calhoun, 2007).

Difficulties in executive control persist throughout development for many autistic children (Luna et al., 2007), and Fan (2013) suggests that this may be the underlying cause of the atypicalities in both selective and executive attention. The explanation for this is that both selective and executive attention tasks require the ability to control one's attention; in the case of selective attention, tasks usually require a participant to orient to target stimuli while ignoring distractors, which requires a certain level of attentional control. As executive attention tasks are typically more complex, more advanced levels of executive control are necessary. For example, shifting attention requires the ability to both disengage from the current target and successfully orient to the new target. Both of these abilities have been found to be atypical in autism (Courchesne, 1990; Renner et al., 2006) and managing them arguably requires executive control. In the case of divided attention in the current study, participants must control their attention by attending to both visual and auditory stimuli simultaneously. Not only must participants attend to two independent tasks in different modalities, but they also need to draw upon motor abilities (i.e. to circle targets using a pen) and verbal ability (i.e. to say aloud the number of beeps they heard at the appropriate time). This complex process must undoubtedly require elements of executive control. This also links to the theory of executive dysfunction in ASD (Pennington & Ozonoff, 1996; Hill, 2004), suggesting that the patterns of attentional ability in ASD may be related to atypicalities in executive function.

Overall, the current findings not only concur with previously published literature relating to the attentional characteristics of children with an ASD, but they also support the multi-computational theory of attention (Posner & Petersen, 1990). The finding that different patterns of attention abilities exist in ASD compared to TD supports the notion that these three attentional components are separate but related constructs that develop independently of one another; if this was not the case, the attentional profile in ASD would be more balanced (i.e. poor across all three attention components).

3.4.2 Attention and academic achievement in ASD

As predicted, divided attention was related to maths achievement in children with ASD, which concurs with previous findings (May et al., 2013), in that children who were better able to divide their attention between auditory and visual tasks had higher maths achievement scores. The current study also provided the novel finding that divided attention was related to reading achievement. May et al. (2013) did not find executive attention to be related to reading achievement, however, this could be attributed to the fact that their measure captured basic word reading and did not encompass more complex reading abilities such as reading comprehension. The current study did, however, include a composite measure of reading achievement, which may explain this discrepancy between the findings of these two studies. Neither sustained nor selective attention were related to the achievement measures, therefore divided attention seemed to be more relevant for achievement in this sample. Based on this, it was possible to use divided attention performance to create subgroups of autistic children in order to examine profiles of achievement based on attention ability. The findings of these analyses will be discussed in the following sections.

3.4.2.1 Aspects of reading achievement

As the existing literature suggests that children with an ASD appear to have a discrepancy between their basic word reading and reading comprehension performance (Huemer & Mann, 2010; Jones et al., 2009; Kim et al., 2018; Nation et al., 2006), it was predicted that similar profiles of achievement existed in the current sample. In a novel attempt to determine whether attention plays a role in characterising profiles of reading achievement, word reading and reading comprehension abilities were compared within and between subgroups of children based on their divided attention ability. When comparing children who had either failed to complete the divided attention measure, or scored at floor, to those who performed within the normal range, differences in the patterns of their reading abilities were found. Children with poorer divided attention had significantly lower reading comprehension scores than the children with better divided attention, despite the fact that there was no difference in word reading between the subgroups. This suggests that divided attention plays a role in the ability to understand the meaning within passages of text. In addition to this, children with poorer divided attention had a significant discrepancy between their word reading and reading comprehension, while no such discrepancy existed for the children with better divided attention. The subgroups did not differ significantly on IQ, suggesting that divided attention ability was more relevant in characterising the differences between subgroups, rather than general cognitive ability.

Previous research has suggested that the discrepancy between word reading and reading comprehension could be attributed to decoding ability (Nation et al., 2006), while others contradict this, finding non-word decoding to be typical in children with an ASD (Huemer & Mann, 2010) and therefore argue that it cannot be the cause of reading comprehension problems. Further to this, studies of TD children have found that less skilled reading comprehenders do not differ from skilled comprehenders in phonological processing ability, but that performance on a working memory task that defined the difference between these groups (Cain, Oakhill & Bryant, 2000). In the current sample, pseudoword decoding performance was comparable to that of basic word reading, and scores on both of these measures did not differ between children with better and poorer divided attention. This concurs with the findings of Huemer and Mann (2010), suggesting that decoding is not necessarily of importance in the ability to understand the meaning within passages of text. Together, these findings suggest that a discrepancy between basic word reading ability and the more complex ability to be able to understand the meaning of text passages does exist within children with ASD. Furthermore, as the discrepancy was present only in children with poorer divided attention, divided attention may play a role. When reading a passage of text, one is required to not only attend to the structure and phonetics of a word, but also to the word's meaning, as well as its meaning within the context of the whole passage; it therefore follows that being good at managing the multiple demands on attention that reading comprehension engenders enables better understanding of the passage as a whole.

3.4.2.2 Aspects of maths achievement

As recent research has suggested that for children with an ASD there are discrepancies between aspects of maths achievement, particularly between calculation and reasoning abilities (Wei et al., 2015; Miller et al. 2016), it was predicted that there would be similar profiles of maths achievement in the current sample. Further to this, as it is known that executive control is predictive of maths in children with ASD (May et al., 2013), it was predicted that these profiles would be different, depending on a child's divided attention ability. Indeed, when children's mathematical reasoning was compared with their numerical operations performance, it was found that children with poorer divided attention showed a discrepancy between these different aspects of maths ability, whereas children with better divided attention performed similarly across both measures. This suggests that difficulties with more complex mathematical tasks (i.e. reasoning and problem solving) exist, but only for children who have poorer divided attention skills. Although it is known from the extant literature that these profiles of maths achievement may exist within children with ASD (Wei et al., 2015; Miller et al., 2016), the finding that these discrepancies may be defined in part by attention ability is novel.

It is, however, important to note that unlike the comparison of aspects of reading achievement, children with poorer divided attention performed less competently on both maths tasks than children with better divided attention. This suggests that their overall maths ability is weaker, rather than weakness in a particular aspect of maths ability, and that divided attention plays a role in this. Drawing upon the ADHD literature, Biederman et al. (2004) found that children with ADHD who had executive functioning difficulties had significantly poorer maths ability than children with ADHD without executive functioning difficulties. Furthermore, both groups of ADHD children had poorer maths ability compared to TD controls. The authors proposed that the combination of ADHD symptoms and executive dysfunction compounded maths ability for these children. Indeed, a similar pattern in relation to divided attention was observed in the current study; autistic children had poorer maths ability than TD children, and when creating subgroups of autistic children on the basis of divided attention ability, those with poorer divided attention also had weaker maths achievement. This suggests that autistic children who also have poor divided attention ability are more at risk for difficulties with maths achievement and are an important group to focus on in future research.

Overall the findings reinforce the notion that divided attention is important for maths in children with an ASD as it plays a role in defining distinct profiles of maths achievement. Children who have both poor divided attention and ASD may require more support with mathematics than those autistic children who have average or good divided attention.

3.4.3 Cluster analysis findings

Three distinct transdiagnostic subgroups of children emerged from the cluster analysis that were characterised by children with good, average, and poor divided attention and academic achievement respectively. It is important to note that this analysis did not capture all of the children with an ASD, but only those who scored 1 or above on the divided attention measure (N = 22), compared to the analyses conducted previously in this chapter which was able to represent all children.

The subgroups captured distinct profiles of achievement, as defined by divided attention and maths and reading achievement scores. Children who had average or above average attention and achievement scores displayed a relative strength in their maths achievement, compared to levels expected based on IQ. Conversely, children who had poorer divided attention and maths and reading achievement scores had a discrepancy in their maths achievement, relative to their IQ, and to their reading achievement. The difference between subgroups suggests that divided attention plays a role in maths ability; not only is it clear that divided attention plays a role in characterising children who have a relative weakness in maths, but also those for whom maths is a relative strength. It therefore may be that being able to divide attention between two modalities supports skills relevant for maths achievement, and that maths achievement may be impacted for children whose divided attention skill is weaker. This raises important issues for educational interventions in maths achievement, suggesting that if divided attention abilities are targeted in cognitive training sessions, improvements in this skill may impact upon maths achievement. Indeed, cognitive training can be successful in improving attention (Kirk et al., 2016; Tullo, Guy, Faubert, & Bertone, 2018), therefore future research could consider whether an improvement in attention is also related to an improvement in maths achievement.

3.4.4 The role of intelligence

Mean IQ differed significantly between the three cluster subgroups, and it is likely that it plays a role in the patterns seen here. Indeed, IQ is known to be a strong predictor of academic achievement (Eaves & Ho, 1997), however this is not necessarily the case for autistic children (e.g. Jones et al., 2009; Kim et al., 2018), particularly considering the findings reported in this chapter. Low achieving children with poor attention demonstrated a discrepancy in their maths achievement relative to their IQ that was not observed in the other two subgroups; in fact, children in each of the other subgroups had a relative strength in maths relative to their IQ. Furthermore, the correlation between maths achievement and divided attention in the ASD group were still significant, even when IQ was controlled for. In addition, IQ and divided attention were not significantly related in the TD group. As a consequence, IQ cannot solely explain the differences in these groups, and the findings here suggest that divided attention played a role in defining these unique subgroups.

It is also important to recognise that several children with ASD had substantial difficulties with completing the divided attention task, and although the divide attention subgroups did not differ on the basis of IQ, IQ was overall correlated with divided attention. It is therefore possible that at least in part, poor performance on this task reflected poor comprehension of task instructions for some autistic children. This was, however, only the case for autistic children, as IQ and divided attention were not related for TD children. One possible explanation for this is the wider range of IQ scores within the ASD group, with four children achieving IQ scores less than 70. This raises a question regarding the potential presence of intellectual disability in the ASD group, which has implications for using heterogeneous ASD samples, an important issue that will be discussed below. Overall, the potential relationship between IQ and the divided attention task is a clear limitation of the current study, and this will be discussed further in the relevant section below, however the point to be made here is that this may explain in part the role of intelligence within the relationships observed.

3.4.5 Transdiagnostic heterogeneity

One important and interesting finding was that although most of the children with an ASD fell into the "poor-attention-low-achievers" subgroup, there was evidence of heterogeneity, evidenced by the distribution of children across all three clusters. This finding also demonstrates that the subgroups were not defined by ASD diagnosis. This has important implications for the way in which data are analysed; looking within- and between-groups that are defined by ASD diagnosis does not capture a complete picture and de-emphasises the heterogeneity of ASD (Charman, 2015). Accounting for autism heterogeneity in research does present significant challenges, some of which are discussed in the limitations section below. Future research should consider using data analysis techniques that investigate abilities and behaviours of children transdiagnostically, which can capitalise on the heterogeneity seen in the current study, in order to understand the wider autism phenotype and the role of attention. As alluded to above, there are limitations to the way in which heterogeneity was represented within the current study, which are discussed below.

3.4.6 Limitations

One clear limitation of the current study is the small sample size of both groups, particularly the ASD group, therefore caution should be taken when interpreting the findings from the current study, as clearly this has implications for generalizability. Furthermore, in relation to the issue of heterogeneity within autism, undoubtedly the small sample size of the ASD group is problematic in that a larger sample would be necessary to account for as much within-syndrome variability as possible. Due to this issue, one approach taken within this chapter that attempted to recognise heterogeneity was the use of a transdiagnostic cluster analysis. Conducting cluster analysis with small samples is not ideal, however this transdiagnostic approach to analysing the data was exploratory, and not intended to be used to make broad claims; rather, the purpose was to investigate whether children within each diagnostic group clustered together or were distributed across different clusters. In this sense, the aim was achieved and has highlighted the importance of considering cognition in autism transdiagnostically. In addition, it could be argued that as the clusters were characterised by participants who had above average, average and below average attention and achievement, this adds little over and above the linear correlations reported. However, this exploratory analysis has shown that different profiles of achievement exist between clusters, which is a finding that correlational analyses alone cannot identify. Discrepancies between IQ and maths achievement existed in both clusters A and C, but not in cluster B. Furthermore, the IQ-maths discrepancies differed between clusters A and C, in that cluster A achieved maths scores higher than expected for their IQ, and lower than expected for cluster C. Indeed, the overall sample size is small, and sample sizes between clusters are unequal, however similar patterns have been observed in the literature (Chen et al., 2019) suggesting that the findings here hold some validity. Furthermore, the current study suggests for the first time that attention ability may play a role in defining these patterns, pointing the way for further investigation with larger samples.

Another limitation of the current study, related to the above points about heterogeneity, was the validity of the divided attention subgroup comparisons. The "poorer divided attention" subgroup was comprised of children who either did not complete the task, or who performed at floor; by comparison, the "better divided attention" subgroup included children who performed between 2 SD below average and 2 SD above average. This comparison is therefore potentially problematic, considering the variability of scores was not comparable between groups. Ideally, three groups of children would have been created, characterised by children performing at floor/non-completers, children performing below average to average, and children performing average to above average. Although this would have been a more balanced comparison in relation to subgroup heterogeneity, sample size did not allow for this. As with the cluster analysis, however, comparing groups in this way highlighted different profiles of reading and maths achievement characterised by divided attention that could be investigated further using larger sample sizes. Importantly, a group of children who are often underrepresented in the autism literature were represented in this study, which is a novel approach to recognising heterogeneity in autism research.

As discussed above, several children performed at floor or could not complete the divided attention task. This highlights a possible issue with the task chosen for this study. As mentioned in the introduction, the TEA-Ch has been used successfully with ASD populations in the past (e.g. Henry et al., 2017; Kenworthy et al., 2009), which is one of the reasons it was selected for the current study. It is possible, however, that autistic children with a wider cognitive ability were represented in the current study compared to previous literature. Indeed, within this field of achievement in autism, most studies include groups of participants in the "higher functioning" range of the autism spectrum (Keen et al., 2016) and as a consequence, children with lower IQ are underrepresented (linking to the issues of heterogeneity above). The instructions for the SkySearch DT task do arguably require a certain level of comprehension ability, which was potentially an issue for some children. This was mentioned above in relation to intelligence, and it is important to recognise that although IQ and divided attention were correlated in the ASD group, IQ cannot solely explain ability to complete this task, due to the fact that the divided attention subgroups did not differ on IQ scores. Managing this balance between including a heterogeneous ASD sample and ensuring task appropriateness across participants within a single study is difficult, however, the following chapter of this thesis will address this issue by using attention measures that require minimal instruction.

Finally, although the use of standardised measures allowed for comparisons while accounting for age, and are well-established measures with high reliability and validity, they do lack ecological validity. The factors at play within the classroom environment are complex, therefore to fully understand the relationship between attention and learning in autism, some of these aspects of the classroom must be taken into account. For example, Fisher et al. (2014) investigated this relationship by conducting lessons in a mock classroom, manipulating distraction between conditions, and measuring learning from that lesson. Similarly, Hanley et al. (2017) created video lessons and used eye-tracking to capture visual attention patterns during the lesson which was analysed to determine whether these patterns of attention were related to how much children learned from the lesson. Related to this, it is also important to consider how attention during a task impacts upon task performance. Although the measures used within the current study are reliable measures of achievement and attention, they are entirely independent tasks. Measuring attention during a task allows for a more detailed investigation of how attention impacts upon learning from that task, which is more representative of the mechanisms at play in the school setting. These are issues that the following chapter will take into account.

3.4.7 Conclusions

Overall, the current study has investigated the role of attention in academic achievement for children with ASD. With this timely study it has been possible to enhance the extant literature with novel findings. Examination of academic achievement profiles between subgroups of children with ASD supported the existing literature that has found different profiles of reading and maths achievement exist within this population (e.g. Jones et al., 2009; Kim et al., 2018). In a novel addition to the literature, the findings from this chapter suggest that these profiles may be characterised in part by divided attention ability. The exploratory cluster analysis demonstrated the importance of considering children with an ASD not only within-syndrome, but also transdiagnostically. The cluster analysis also reinforced the finding that divided attention is important for maths achievement, in that it characterised three distinct subgroups of children, who showed either strengths or weaknesses in maths achievement (compared to their IQ), based on whether their divided attention was above, at, or below average. Although in this study it was important that the measures of attention and achievement were standardised, future work should consider more ecologically valid measurements of attention and learning to investigate this relationship further, particularly considering the issue of task demands. This is an approach taken in the following chapter.

Chapter Four: Studying attention and learning using eye-tracking

4.1 Introduction

In Chapter Three, the relationship between attention and academic achievement was investigated with the use of standardised assessments, which offer established reliability and validity measurements of abilities in children and can account for differences in age. One disadvantage of these measurement tools, however, is that they are not necessarily reflective of real-world abilities and behaviours. This chapter will therefore focus on examining the relationship between attention and learning using methods that more readily reflect classroom-based attention and learning. Furthermore, as discussed in detail in Chapter Three, some children with ASD found the attention measures from the TEA-Ch difficult to complete, and it was hypothesised that this may have been partially due to the complexity of the task instructions, meaning that for some children performance on this task may not have reflected true attention ability. The study reported in this chapter will therefore use measurements of attention that require simple instruction.

4.1.1 Attention and learning in the classroom

As described in the previous chapters, evidence suggests that there may be a relationship between attention and learning in an academic and structured context. As previously discussed, the ability to pay attention is crucial for learning in TD children (e.g. Erickson et al., 2015). Since autistic children are known to have variable academic outcomes and a different attentional profile to TD children, understanding the relationship between these aspects is important, as it may highlight ways to support autistic pupils at school and even improve their learning outcomes. Research, including the previous chapter of this thesis, has reported that such a relationship may exist. Despite this, so far the investigations have been specific to standardised measures of achievement. In order to gain a richer understanding of this relationship, it is also important to measure these abilities in an ecologically valid context. One example of this was conducted by Fisher, Godwin and Seltman (2014), as described in Chapter One. In their study, the visual displays within a classroom were manipulated (i.e. decorated vs. sparse) and looking behaviours of TD children were coded as on-task or off-task as a measure of attention. They then measured learning using worksheets after the lessons, and found children spent more time off-task and achieved poorer learning outcomes in the decorated condition. This provides evidence of the relationship between attention and learning in an ecologically valid setting, however the measure of attention was somewhat subjective. In a later study, the researchers found that objective measures of sustained-selective attention (using a computerised task and eye-tracking) correlated with learning outcomes (Erickson et al., 2015), strengthening their findings from the classroom-based study. While the findings are important in terms of relating objective measures of attention to learning, these measures were taken from tasks independent of one another; it is also important to consider whether attention during task performance is related to how much is learnt from that task. Furthermore, the previous studies only examined the relationship between attention and learning in TD populations.

4.1.2 Eye tracking

Eye-tracking technology is a growing tool in psychology used to measure visual attention, in both typical and atypical populations. It is a precise method of measuring visual attention, providing rich data regarding an individual's attention allocation during a task (see Hanley, 2015). The assumption here is that what a person is looking at reflects what they are thinking about (Yarbus, 1967), and although it is entirely possible that a person may be looking at one thing but attending to something else, for example an auditory stimulus, visual fixation is a well-established proxy for attention. In autism research, eye-tracking technology has been used extensively to help inform the theory of attention in ASD, particularly in studies of social attention (e.g. Klin et al., 2002; Riby & Hancock, 2008; Hanley et al., 2014) due to the social atypicalities that characterise autism. Emerging research is using eye-tracking in a variety of contexts, such as non-verbal measures of spatial working memory (Fanning, Hocking, Dissanayake, & Vivanti, 2018) and gaze-contingent attention training (Powell, Wass, Erichsen & Leekham, 2016).

The most relevant example of the use of eye-tracking in autism research, Hanley et al. (2017), was described in detail in Chapter One. This study used video lessons presented on a computer screen to i) measure attention by tracking the eye-movements of TD and ASD children, and ii) investigate whether patterns of visual attention (i.e. looking at the teacher vs. the background) were related to how much children learned from the lessons. Similarly to Fisher et al. (2014), the authors were also interested in the impact of the background of the video, therefore they manipulated the background to either contain a large amount of visual displays (high visual distraction; HVD), or no displays at all (no visual distraction, NVD). They found that autistic children spent more time looking at the background than at the teacher compared to TD children, but more time spent looking at the background in the HVD condition led to poorer learning outcomes for all children. These findings make an important contribution to understanding the relationship between attention and learning, for both TD and ASD children. However, the main purpose of the study was to evaluate the impact of visual displays, and therefore the visual background conditions were designed at the extremities. As Barrett et al. (2015) have found that both too much and too little complexity of visual displays in classrooms can negatively impact on learning, it is also important to consider the impact of attention upon learning in conditions where the visual background is more balanced.

4.1.3 Attention Network Task

The attention network task (ANT; Fan et al., 2002) is a computer-based measure of attention that has been adapted for children, and has been used extensively in TD populations, as well as with children with ADHD and ASD (e.g. Keehn, Lincoln, Muller, & Townsend, 2010; Pozuelos et al., 2014; Rueda et al., 2004; Samyn, Roeyers, Bijttebier, & Wiersema, 2017). The ANT measures attention based on Posner and Petersen's (1990) theory that attention is comprised of three functional components, alerting, orienting and executive, as outlined in Chapter One. The ANT allows for a practical examination of these components of attention. The alerting function encompasses tonic and phasic alertness; tonic alertness reflects "general wakefulness", while phasic alertness refers to response readiness. Together, they reflect an ability to sustain attention in anticipation of a stimulus and could be described as what previous chapters have referred to sustained attention. The orienting function refers to the ability to direct one's attention to specific information and can involve shifting attention from one object to another; this is similar to the description of selective attention, which has been referred to in previous chapters. The executive function of attention maps on to earlier descriptions of this attentional construct, which requires more complex mental operations, usually during conflict. The ANT is therefore theoretically underpinned by the multi-computational model of attention, providing a measure of each attentional component within a single task.

The child version of the ANT, developed by Rueda et al. (2004), has been used extensively in TD populations, and as described in Chapter One, combines Posner's cueing paradigm (Posner, 1980) with a flanker task. Children are presented with a central directional target (pointing left or right) flanked with congruent or incongruent distractor targets and are asked to press the button that reflects the target's direction. Trials are manipulated in three key ways in order to evaluate the three attention networks. To measure orienting, a spatial cue is presented either in the position the target will appear (valid cue), in the opposite position the target will appear (invalid cue) or not at all. To measure executive attention, the target is flanked by targets that are either congruent or incongruent with the direction of the central target. To measure alerting, an alerting cue either precedes the target to alert the participant to its arrival, or no cue is given. In the original child version of the ANT, this alerting cue was visual, appearing just before the orienting cue. However, Callejas, Lupianez and Tudela (2004) argued that the use of this visual alerting cue does not allow for measuring each network independently, therefore they adapted the adult version of the ANT to use a short high-frequency alerting tone to cue the target, instead of the visual cue. Some researchers have since also used this in the child version of the task, such as Pozuelos et al. (2014), who investigated the developmental trajectories and interactions of the attention networks in 6- to 12-year-old TD children. As discussed in detail in Chapter One, they found evidence to support the notion that each attention network has a separate developmental trajectory.

As already discussed in previous chapters, existing research suggests that the ability to sustain attention is typical in most children with ASD, but that selective and executive attention may be abilities that this group has some difficulty with. Fan (2013) suggests that due to the orienting and executive atypicalities in ASD, it follows that the orienting and executive attention networks may not function efficiently in this group. This theory is, on the whole, supported by findings from several studies that used a visual alerting cue (Keehn et al., 2010; Mutreja, Craig, & O'Boyle, 2015; Mash et al., 2018; Hames et al., 2016). For example, Keehn et al. (2010) used the adult version of the ANT with 8 to 18-year-olds with autism, and found that orienting network scores were lower in the autism group compared to a TD sample, suggesting less efficient orienting attention in this group. Similarly, Mutreja et al. (2015) found that children with autism (5 to 11-year-olds) were slower to respond on spatially cued trials compared to TD children, supporting the theory of an atypical orienting network. In addition to this, they found that autistic children made more errors on incongruent trials, implying difficulties with executive attention. It is important to note that this study used the child version of the ANT, which may be why the findings were slightly different (as well of course as individual differences between the autistic features of the ASD samples in these studies and developmental differences). Hames et al. (2016) also used the child ANT, but with a much smaller sample of 6 ASD and 6 TD adolescents (aged 15-17 years), in an fMRI study. Their findings corroborated with the previous finding that orienting was poorer in ASD compared to TD, but by comparison, they found that executive attention was similar between groups. This was, however, a very small sample, therefore interpretation must be made with caution.

Two papers have used the auditory alerting cue version of the ANT in children with ASD, which are appropriate comparisons for the study described in this chapter. Samyn et al. (2017) used the adult version of the ANT with boys with ASD, ADHD, or who were TD. They found that when examining reaction time, there were no differences in alerting, orienting or executive attention between the ASD and TD children, suggesting that the autistic children were performing similarly to TD children in these domains. However, boys with ASD seemed to have atypical alerting network in relation to accuracy; they made a similar number of errors regardless of whether or not the alerting tone preceded the target. This was also the case for boys with ADHD. By comparison, TD boys made more errors when a warning tone was present. The fact that the boys with ASD performed similarly to those with ADHD is striking, particularly when we consider that one of the core features of ADHD is impairments in attention. Faja, Clarkson and Webb (2016), however, only investigated executive attention in their study, which was conducted with 7 to 11-year-olds with and without ASD. They found that children with ASD were slower and less accurate than TD children, and that their accuracy (but not reaction time) was affected by whether flanker direction was congruent or incongruent with the direction of the target.

Taken together, the findings within this body of literature are highly variable, especially when comparing studies using different versions of the ANT, both in terms of adult or child versions, as well as the nature of the alerting cue (i.e. visual or auditory). It is therefore difficult to summarise the findings of these studies, however it does appear that autistic children tend to perform atypically on the ANT, although there is no consensus with regards to which attention network these atypicalities relate to.

4.1.4 Aims and scope of current study

The first aim of the current study was to investigate attention abilities within the framework of the multi-computational model of attention (i.e. alerting, orienting and executive attention) between children with and without ASD, using the child version of the ANT with the auditory alerting cue to allow the evaluation of each network independently. The purpose of this was to consider whether the attentional profiles of children with autism are typical or atypical in comparison to TD children, and as a consequence, advance our theoretical understanding of attention in ASD. The child ANT was chosen due to the simplicity of its instruction (following the challenges of using the TEA-Ch in Chapter Three), its suitability for both TD and ASD children, the short duration required to complete the task, and its ability to provide measures of three attention abilities within a single task. Based on the existing literature, differences between diagnostic groups should be expected. That said, research using the ANT in this group is inconsistent in design, and subsequently their findings are also difficult to synthesise; as a consequence, it is difficult to make precise predictions. The one paper that has used the auditory alerting cue in a study including children with ASD (Samyn et al., 2017) indicates that the alerting network in relation to accuracy may be less efficient in ASD, therefore this would be a valid prediction to make for the current study. Based on the findings of the same paper, it would be sensible to predict no differences between groups in relation to orienting or executive attention. It is, however, important to note that the adult version of the ANT was used in that particular paper.

The second aim of the current study was to observe patterns of visual attention during a task using eye-tracking, and to investigate whether any differences existed between groups. To do this, the video lessons created by Hanley et al. (2017) were used, but rather than manipulating the background to be either highly visually distracting or to contain no visual distraction, a "middle ground" background was created for this study (as the original stimuli from Hanley et al (2017) used a green-screen so that it was possible to systematically change the background), containing three posters from a primary school classroom. As already discussed, research has shown that both too much and too little visual stimulation can be detrimental to learning outcomes (Barrett et al., 2015), therefore a middle ground was chosen in order to i) retain the context of a typical classroom environment, and ii) to provide a variety of visual stimulation but not over-saturate the visual content of the video. Based on the vast existing literature that suggests individuals with ASD spend less time looking at social information compared to non-social information (Klin et al, 2002; Riby & Hancock, 2008; Hanley et al., 2014), the prediction here was that children with ASD would spend less time looking at the teacher compared to the background of the video. Autistic children were also expected to spend less time looking at the teacher compared to TD children.

The third aim was to investigate the relationship between attention abilities, visual attention, and learning, and to determine the strongest predictors of learning based on these factors. This would draw together the ANT, eye-tracking and learning data. As demonstrated in Chapter Three, and supported by the existing literature, attention and academic achievement appear to be related, therefore it was expected that attention abilities would predict learning. Based on the findings described in Chapter Three, the expectation was that executive attention would best predict learning, although Hanley et al. (2017) found that sustained attention was the strongest predictor of learning in this particular lesson-based task, therefore it is also possible that alerting is important here. Furthermore, based on the findings of Hanley et al. (2017) it was also predicted that attention to the teacher would be related to and predict learning outcome, in that children who spent a longer time looking at the teacher would learn more from the lesson. Furthermore, significant relationships between components of attention abilities and visual attention (as measured by eye-tracking) were expected. In other words, measures of attention abilities were expected to be related to time spent looking at the teacher vs. the background. As no prior literature has investigated this, this was an exploratory analysis, and no specific predictions about which attention abilities would be related to visual attention were made.

Due to the finding in Chapter Three that children were grouped on attention, maths and reading regardless of whether or not they had a diagnosis of ASD (i.e. both TD and ASD children were present in each cluster), the current chapter aimed to take a transdiagnostic approach to data analysis. Therefore in this chapter, data were analysed first by full sample (i.e. TD and ASD participants together), and then by group.

4.2 Method

4.2.1. Participants

In total, 27 autistic children and 36 TD children were recruited through primary schools, local contacts, and the ASD-UK database. Due to a variety of circumstances, complete data sets could not be obtained for all children. Reasons for this included difficulties completing eye tracker calibration (N = 14), technical issues with eye tracking equipment or ANT during testing (N = 8), poor performance (at/below chance) or inability to complete the ANT (N = 4), school absence on testing dates (N = 2), or request to withdraw during testing (N = 1). Complete data sets were obtained for 34 children (12 ASD, 22 TD), and for 48 children (21 ASD, 27 TD) ANT, learning outcome and IQ data were obtained. This therefore resulted in two samples, one larger sample without eye-tracking data (full sample) and a smaller sample with eye-tracking data (subsample). The full sample consisted of 21 autistic children aged between 7 and 12 years (M = 117.8 months) and 27 TD children aged between 7.5 and 10.5 years (M = 106.8 months). TD and ASD groups were matched based on FSIQ. A higher ability ASD sample was necessary due to the requirements of the experimental tasks. The subsample was used to analyse eye tracking data, consisting of 12 children with ASD (M age = 121.4 months) and 22 TD children (M age = 106.6 months). Similar to the full sample, these groups were matched on FSIQ.

4.2.2 Tasks and stimuli

4.2.2.1 Attention Network Task (Child Version)

A modified version of the child attention network task was used, similar to the version described in Pozuelos et al. (2014), presented on a laptop and run using E-Prime Version 2 software. The aim of the task was to determine the direction of a central target fish, which pointed either left (50% trials) or right (50% trials) and was flanked by two fish either side (see Figure 4.1). The efficiency of each attention network was evaluated by observing the impact of an alerting tone, spatial cues, and flankers upon reaction time and percentage of errors.

The target fish appeared either above or below a central fixation cross, which remained on screen for the duration of each trial block. In half of the trials, the flanker fish pointed in the same direction as the target fish, and in the other half they pointed in the opposite direction.

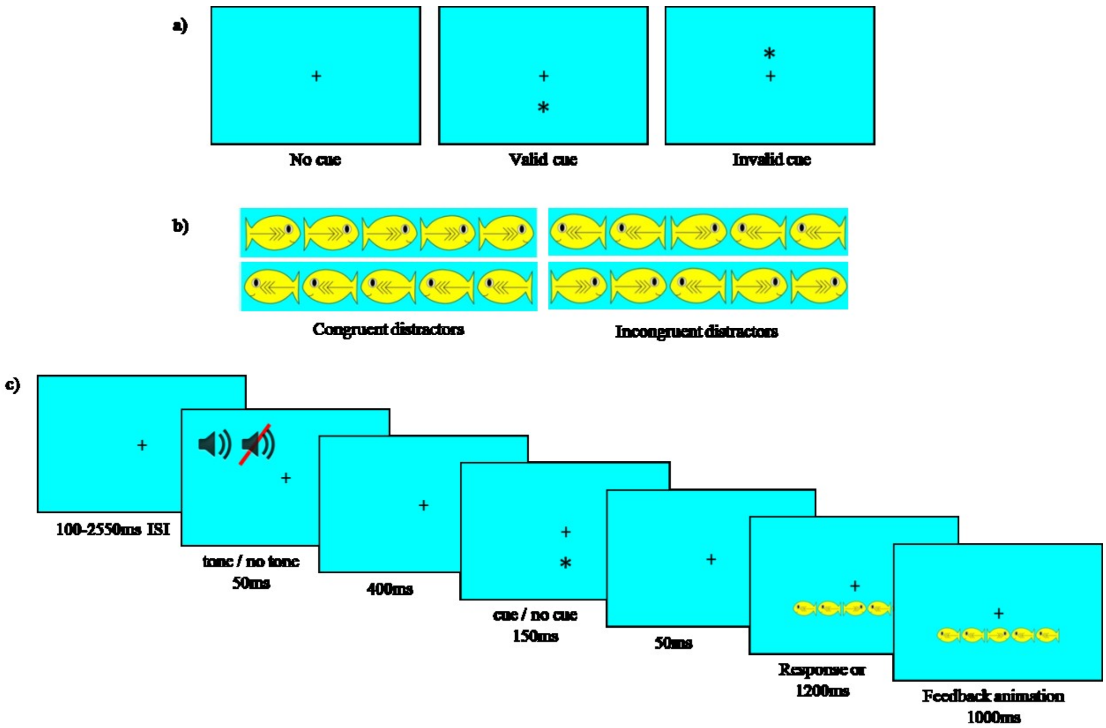

Figure 4.1. Illustration of the ANT, including a) orienting cue types, b) flanker types and c) trial sequence.

All trials began with either a 50ms 2000hz alerting tone (50% trials) or a blank frame for 50ms with no tone (50% trials). Following this, on two thirds of the trials, visual orienting cue (an asterisk) was presented. In the remaining one third of trials, no cue was presented. In the trials in which an orienting cue was presented, 50% of the time it was presented in the location congruent with where the target fish would appear (valid cue) or in the opposite location (invalid cue). The target array remained on the screen for 1200ms or until a response was made. At the end of each trial, feedback lasting 1000ms was provided in the form of animation; the target fish smiled and blew bubbles for correct responses or cried for incorrect or omitted responses. A visual representation of the trial sequence and cue types is presented in Figure 4.1.

The task began with an instruction block with 4 trials, during which the researcher explained the task to participants. They were told that a fish would appear either above or below the fixation cross and that their task was to decide which way it was swimming and press a button on the keyboard that matched the direction. Arrow stickers were placed on top of the “A” key pointing left, and “L” key pointing right. They were told that other fish would be alongside the middle fish, but that they should only choose which way the middle fish was swimming. This instruction was followed by a repeatable six trial practice block. Participants

Table 4.1. Calculations for each network score

Network score		Trial type		Trial type
Alerting RT	=	No tone RT	-	Tone RT
Alerting % errors	=	No tone % errors	-	Tone % errors
Orienting RT	=	Invalid cue RT	-	Valid cue RT
Orienting % errors	=	Invalid cue % errors	-	Valid cue % errors
Executive RT	=	Incongruent flanker RT	-	Congruent flanker RT
Executive % errors	=	Incongruent flanker % errors	-	Congruent flanker % errors

were able to complete the practice block up to two times or until they felt confident with the requirements of the task. Following this were three experimental blocks of 48 trials, a total of 144 experimental trials. Between each block, participants could take a short break of up to 2 minutes, or once they stated they were ready to continue. Of these 144 experimental trials, there were 12 trials for each of the 12 experimental conditions: 2 (tone, no tone) X 3 (valid cue, invalid cue, no cue) X 2 (congruent, incongruent). Conditions were chosen randomly for each trial. Response speed and accuracy of each trial was recorded.

Attention Network scores based on reaction time (RT) and percentage of errors were calculated as per the literature, therefore providing two scores for each network (see Table 4.1). The alerting score was calculated by subtracting performance (i.e. median RTs or percentage or errors) in trials with tone from trials without a tone. When participants are presented with an alerting tone, they are primed to attend to the upcoming target, whereas in trials without a tone they receive no cue to indicate when the target will appear. The orienting score was calculated by subtracting performance in trials with a valid orienting cue from those with an invalid orienting cue. The presentation of a valid cue informs the participant where the target will appear, compared to trials with an invalid cue that provide no useful spatial information about the target's location. The executive attention score was calculated by subtracting performance in trials with congruent flankers from trials with incongruent flankers. Incongruent flankers provide conflicting information about the correct response, therefore participants are required to ignore this information to respond. In congruent conditions, no such conflict exists.

For each attention network, the difference between the relevant conditions provided a measure of the efficiency of that network. Positive scores indicate higher efficiency of the attention network, as this means participants have successfully used the relevant information to make a response (i.e. tone, cue or flankers), responding quicker or more accurately in conditions where this information is useful, compared to when it is not. Scores closer to zero indicate that participants have performed similarly between conditions, suggesting reduced attention network efficiency.

4.2.2.2 Video mini-lessons

Participants watched three mini-lessons, each lasting approximately 5 minutes. The content of the lessons was taken from history lessons on the Irish primary school curriculum and were about Irish myths and legends (Lesson 1, The Salmon of Knowledge; Lesson 2, Oisin and the Land of Youth; Lesson 3, The Legend of Cuchulainn). The content was chosen as it was age-appropriate and likely that children would have not been previously exposed to the lesson content. Videos were always watched in the same order (i.e. Lesson 1, Lesson 2, Lesson 3).

In each lesson, a "teacher" who was in the centre of the frame, looking forward, delivered a story. At the start of each lesson, the teacher told the child to listen carefully as they would be answering some questions at the end of the lesson. The videos were filmed in front of a green screen so that the background of the video could be manipulated using computer software. In the background of each video, there were three posters taken from real primary school classrooms (see Figure 4.2). The location of the posters was counterbalanced across the three videos. As described in the introduction to this chapter, a "middle ground" level of visual background information was created. Previous research has examined the level of distraction that each poster incites for TD children (Grew, 2015 *unpublished*), and these findings were used to select three posters. The "bugs" and "cats" posters were both used in the original task and were found to attract attention less than the alternatives. The "map" poster was not used in the original study but was included as its colours and features were most similar to the "bugs" and "cats" posters.

At the end of each lesson, participants completed worksheets to measure learning (see Appendix A). The worksheets were validated prior to this study with 20 children from mainstream schools aged 7 to 11 years who had not watched the video lessons, to ensure that the worksheets were measuring learning as opposed to verbal reasoning (i.e. deciphering the answer to a question based on its wording). Only questions that were answered correctly at or below chance level in the validation study were included in the worksheet (see Appendix B for validation data). Worksheets consisted of eight multiple choice questions to probe recognition and five open-ended questions to probe comprehension. Answers to the open-

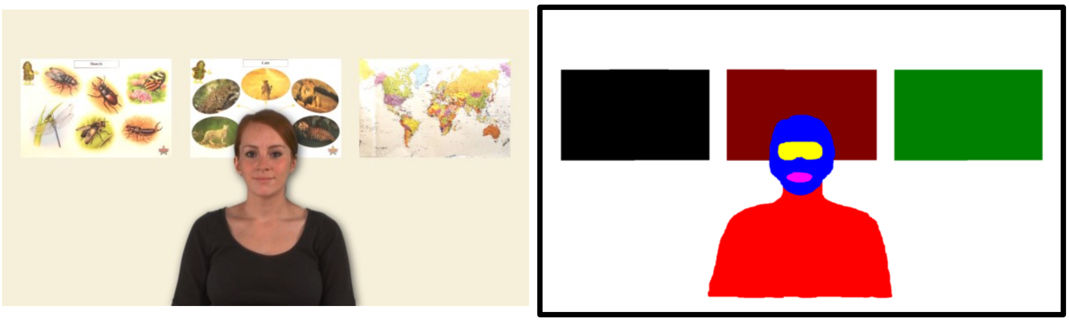

Figure 4.2. Screenshot from video lesson (left) and mark-up of AOIs (right).

ended comprehension questions could be awarded up to two points based on the quality of the answer, meaning a maximum of 18 points was possible for each lesson (see Appendix A for examples of scoring). To ensure points were awarded consistently, a quarter of the worksheets were scored by a second researcher, with an inter-rater agreement of 88%.

4.2.2.3 Eye-tracking

An SMI Remote Eye Tracking Device (RED) 250 was used to record participants' eye movements. This was a portable system, consisting of a 22-inch monitor with an infrared eye tracking device attached to the bottom of the screen. This is a completely non-invasive method as the device uses invisible infrared light to track the participant's eye movements, therefore participants can view the screen as they would naturally. The eye-tracker sampled at 250hz and had an accuracy of 0.5 degrees visual angle or less, which was confirmed with the use of a 9-point calibration and 4-point validation procedure before each video. Participants sat approximately 60cm from the screen.

A bespoke program made for the original study (Hanley et al., 2017) was used to analyse the eye tracking data based on predefined areas of interest (AOI): teacher's face (head, eyes, mouth), teacher's body, the background (left poster, middle poster, right poster, white space) and out of bounds, representing fixations that did not fall in any of the predefined categories (see Figure 4.2 for a mark-up of these AOIs). The AOIs were defined for each frame of the video, allowing for a frame-by-frame analysis. This resulted in 7923 frames analysed for L1, 5775 frames for L2 and 6895 frames for L3. For each frame of the analysis, the program determined the location of fixations. Data were considered in terms of the proportion of fixations made to the AOI compared to total fixations made to the screen (i.e. by summing fixations to teacher's face, teacher's body and background); total number of fixations made differs between participants (e.g. due to looking off-screen, differences in fixation duration), which is clearly problematic for making comparisons. Analysing data in this way therefore allows for more informative comparisons. As in Hanley et al. (2017), the teacher's body AOI was not included in the analysis, as doing so would have meant the looking time data summed 100%, which would be problematic in terms of data analysis.

4.2.2.4 Cognitive ability

Intelligence was measured using the Wechsler Abbreviated Scale of Intelligence, Second Edition (WASI-II) for each participant. This provided scores of verbal intelligence (VCI), non-verbal or performance intelligence (PRI), and full-scale IQ (FSIQ). A full description of this measure can be found in Chapter Three.

4.2.2.5 Social responsiveness

Parents of 14 children with ASD and 5 TD children completed the Social Responsiveness Scale, Second Edition (SRS-2; Constantino & Gruber, 2012), which measured the severity of autistic symptoms for each of these children. The SRS is a 65-item standardised measure, used to ascertain the range of autistic symptoms and includes items that identify a child's social impairments, assess social awareness, social information processing, capacity for reciprocal social communication, social anxiety/avoidance and autistic preoccupations and traits. The items on the SRS are based around the DSM diagnostic criteria for autism spectrum disorders. This is a parent-report scale, and ratings are given on a scale from 1 (not true) to 4 (almost always true) on the basis of the frequency of behaviour, e.g. 'is socially awkward even when trying to be polite'; 'has difficulty relating to peers'; 'seems overly sensitive to sounds, textures or smells'.

A singular scale score is generated which describes the severity of social deficits whereby high scores indicate a greater severity of social impairment. The SRS is appropriate for children aged from 4 to 19 years, and has been used with TD children, children with ASD, and children with other developmental difficulties (e.g. Williams syndrome; Klein-Tasman et al., 2011). Internal consistency has previously been calculated at .95 (Constantino & Todd, 2003). As most children were recruited through school, direct contact was not made with parents, and this was the main reason for the large amount of missing data in relation to SRS scores. Due to the low response rate, these scores were not used in the main analysis, however they were used in a later analysis of children with ASD. As a consequence, it was also not possible to obtain a measure of internal consistency (e.g. Chronbach's alpha) for this sample.

4.2.3 Procedure

Children were tested either at school, at home, or at the university, and were all tested individually in a quiet room. Testing took place across three 30-minute sessions. In the first session, participants watched Lessons 1 (L1) and 2 (L2) and completed the worksheets.

Table 4.2. Full sample descriptives and group comparisons for age, IQ and learning

	TD (N = 27)	ASD (N = 21)	Group differences
	M (SD)	*M (SD)*	*t*
Age (months)	106.78 (11)	117.76 (19.06)	-2.51*
FSIQ	96.89 (10.24)	93.67 (17.45)	.8
Learning Total	34.37 (7.14)	32.71 (8.47)	.73
Lesson 1 score	12.15 (2.82)	11.38 (2.89)	.92
Lesson 2 score	10.56 (2.67)	10.48 (2.25)	.11
Lesson 3 score	11.67 (3.16)	10.86 (4)	.78

* $p < .05$

The second session consisted of Lesson 3 (L3), the associated worksheet, and the ANT. In the third session, participants completed the WASI-II.

4.3 Results

4.3.1 Full sample – ANT and learning outcomes

This sample consisted of 48 children for whom ANT and learning outcome data were obtained (21 ASD, 27 TD). Mean scores for each measure are presented in Table 4.2. Groups were matched on the basis of IQ, $t(46) = .8$, $p = .43$, $d = .22$, and mean scores were as expected for both groups. In terms of the range of IQ scores, for TD children scores fell within the expected range (i.e. 80-120). The range of IQ scores for ASD children was larger (i.e. 64-125), however this is typical of the heterogeneity of children with ASD. Two children had IQ scores more than two SDs below the mean (i.e. < 70), which can be an indication of significant cognitive impairments, however as these children demonstrated the ability to understand and answer questions from the worksheet, they were included in the analysis. As can be seen in Table 4.2, children with ASD were on average slightly older (chronological age) than the TD group, $t(46) = 2.51$, $p = .016$, $d = .71$, but this was expected as it was desirable to match groups on the basis of IQ rather than chronological age to consider performance on the core tasks.

4.3.1.1 Learning outcomes

Analysis of learning outcome was undertaken by summing performance across all three lessons, meaning the maximum total learning score a child could receive was 54 (i.e. 18 x 3 lessons). As shown in Table 4.2, groups performed similarly on total learning outcome; ASD children scored approximately 1.7 points less on average than TD children, although this difference was not significant, and there was heterogeneity within both groups. In terms of performance between lessons (i.e. for all children), performance was similar for L1 and L3, $t(47) = 1.21$, $p = .234$, $d = .16$, slightly lower for L2 compared to L3, $t(47) = -2.02$, $p = .049$, $d = .26$, and significantly lower for L2 compared to L1, $t(47) = -3.9$, $p < .001$, $d = .48$. To evaluate whether L2 performance impacted data analyses, correlational data patterns including all three lessons were compared to the patterns observed by including only L1 and L3; the removal of L2 data did not change the observed patterns (see Appendix C for correlations using only L1 and L3 data), therefore L2 data were included in the analysis, with the assumption that this lesson was perhaps slightly more difficult than the other two lessons but did not alter the relationship between attention and learning.

4.3.1.2 Attention networks

Attention network scores for median RT (correct trials only) and percentage of errors are presented in Table 4.3. The use of these statistics to represent the efficiency of attention networks is commensurate with previous studies using the ANT (e.g. Pozuelos et al., 2014). Scores indicated that on average, TD participants were faster to respond and made fewer errors in the informative conditions, indicating that efficient attention networks existed. This was mostly also true for ASD participants, except for alerting percentage of errors, which was below zero, suggesting that the presence or absence of the alerting tone did not impact accuracy.

To examine the differences in attention profiles between TD and ASD groups, a repeated-measures ANOVA was conducted with attention network as the within-subjects factor and group as between-subjects factor. This was done for both RT network scores and percentage of errors network scores separately. All multiple comparisons were corrected for using Bonferroni correction.

For RT network scores, the interaction between attention and group was not significant, $F(2, 45) = .454$, $p =.638$, suggesting that attention scores did not differ between ASD and TD groups. The main effect of group was not significant, $F(1, 46) = .308$, $p = .581$. The main effect of attention was, however, significant, $F(2, 45) = 13.21$, $p < .001$, suggesting that attention network scores were different from one another (Figure 4.3). Pairwise comparisons revealed that alerting and orienting significantly differed from one another ($p = .007$), as did alerting and executive ($p < .001$), but that there was no significant difference between orienting and executive scores ($p > .05$). Figure 4.3 suggests a potential difference between groups for executive but not alerting or orienting scores however as the group x attention interaction was not significant, this could not be investigated further.

Table 4.3. Full sample attention network scores by group

	TD (N = 27)	ASD (N = 22)
	M (SD)	*M (SD)*
Alerting RT	33.57 (37.02)	33.14 (35.08)
Orienting RT	65.61 (45.81)	65.21 (52.59)
Executive RT	71.94 (38.01)	61.21 (32.89)
Alerting Accuracy	4.12 (6.07)	-.73 (6.78)
Orienting Accuracy	1.31 (7.15)	.79 (7.61)
Executive Accuracy	6.69 (6.67)	6.81 (7.47)

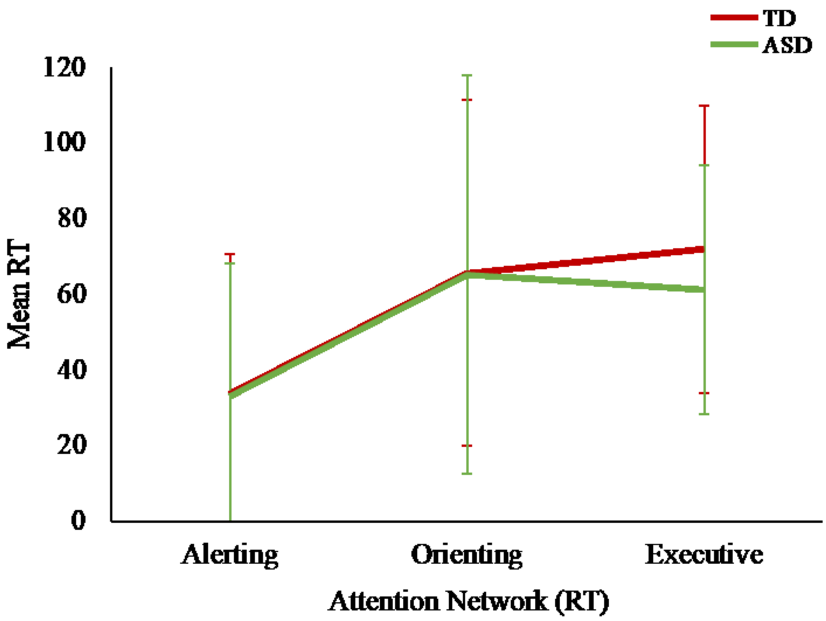

Figure 4.3. Interaction plot for attention RT x group repeated-measures ANOVA.

Similarly, for accuracy network scores the analysis revealed that there was a main effect of attention, $F(2, 45) = 10.07$, $p < .001$, however the interaction between attention and group was not significant, $F(2, 45) = 1.89$, $p = .157$ (Figure 4.4). The main effect of group was also not significant, $F(1, 46) = 2.04$, $p = .16$. Pairwise comparisons for attention indicated that mean alerting and orienting scores did not differ significantly ($p > .05$)

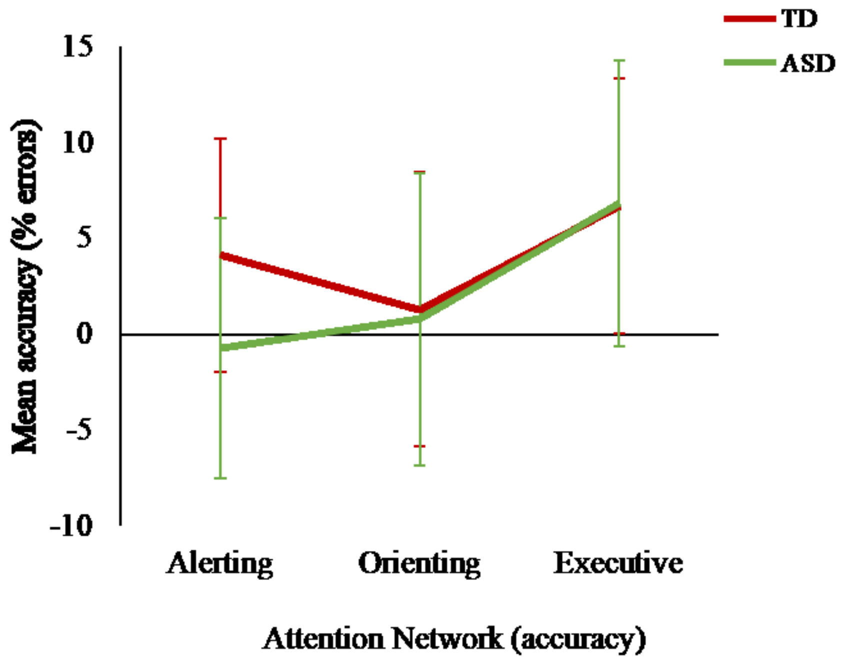

Figure 4.4. Interaction plot for attention accuracy x group repeated-measures ANOVA.

but significant differences between alerting and executive (p < .001) and orienting and executive (p = .003) existed. Figure 4.4 suggests that alerting may have differed between TD and ASD groups, while orienting and executive were similar, however this could not be followed up due to the non-significant group x attention interaction.

4.3.1.3 Correlation analyses

Correlational analyses were conducted to examine the relationship between components of attention and learning outcomes. These were first conducted for the full sample (i.e. TD plus ASD). Analysing the data in this way i) provides more power due to the increased sample size, and ii) provides more variability of scores compared to correlations at the group level. These analyses are presented in Table 4.4, and scatterplots are presented in Figure 4.5. One-tailed correlations revealed that total learning outcome was significantly related to both age and IQ, in that children who were older and with higher IQ achieved higher learning scores. In addition, the correlation with alerting network score (RT) approached significance, $r(48) = .235$, $p = .054$, suggesting that children with a more efficient alerting network achieved higher learning scores (interpreted with caution due to the p value). Neither learning outcome nor IQ were significantly related to any of the other attention network scores.

Table 4.4. Correlation matrix for full sample (N = 48)

	1	2	3	4	5	6	7	8
1. Age								
2. FSIQ	-0.72							
3. Learning outcome	.261*	.692***						
4. Alerting RT	.003	.144	.235					
5. Orienting RT	.03	.171	.001	-.264*				
6. Executive RT	-.147	.230	.195	.249*	.177			
7. Alerting % errors	-.025	-.04	-.064	-.107	.283*	.02		
8. Orienting % errors	.185	-.171	.033	.081	.033	-.084	.075	
9. Executive % errors	-.295*	.006	-.216	-.038	.207	.277*	.255*	-.160

All correlations are one-tailed, *p <.05, ** p <.01, *** p < .001

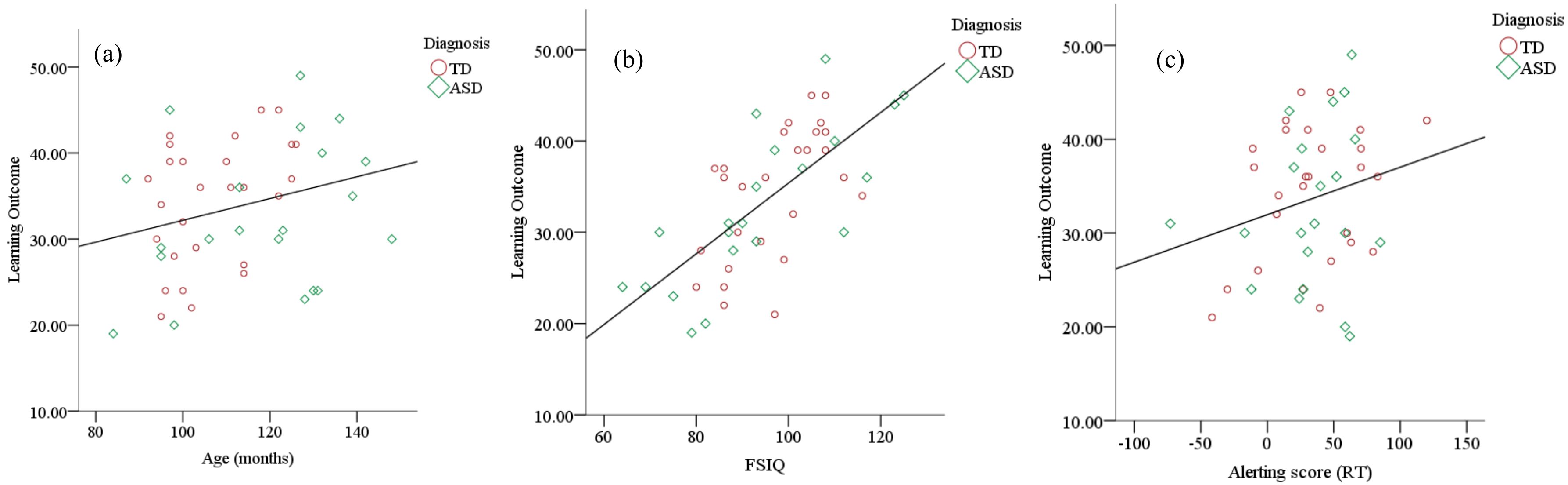

Figure 4.5. Scatterplots with line of best fit plotted for full sample relationships between (a) learning and age, (b) learning and IQ, and (c) learning and alerting RT

For TD children only, a similar pattern existed (see Appendix D for correlation matrix and scatterplots). Total learning outcome was related to age, $r(27) = .41$, $p = .017$, and IQ, $r(27) = .590$, $p = .001$, and the correlation with alerting network score (RT) approached significance, $r(27) = .307$, $p = .06$. In addition, learning was significantly related to alerting network score (% errors), $r(27) = -.358$, $p = .033$, in that children with a larger alerting effect (i.e. less efficient alerting ability) achieved lower learning scores. After examining the data, it appeared that this was driven by an outlier; participant 10 who simultaneously had the highest alerting network score (% errors) and the lowest learning score (see Appendix D, Figure D.1 for scatterplot). When this individual was removed from the analysis, the effect disappeared, $r(26) = -.226$, $p = .133$. Neither learning outcome nor IQ was significantly correlated with any of the other attention network scores (all r's < .28, all p's > .08).

Different correlational patterns existed for ASD children (see Appendix D for correlation matrix and scatterplots). Total learning outcome was significantly related to IQ, $r(21) = .770$, $p < .001$, but not to age, $r(21) = .271$, $p = .117$. In addition, IQ and learning were not related to any of the attention network scores (all r's < .29, all p's > .1). Age did seem to be important in this group, however, as age was significantly correlated with executive network scores, both in relation to reaction time, $r(21) = -.467$, $p = .02$, and percentage of errors, $r(21) = -.453$, $p = .02$, suggesting that older children were less affected by the congruency of flankers. In addition, age was significantly correlated with alerting network score (% errors), $r(21) = .378$, $p = .045$, suggesting older children had a larger alerting effect in relation to accuracy.

4.3.1.4 Predictors of learning

Due to statistical power, a multiple linear regression was conducted for the full sample only. Diagnosis was not entered as a predictor of learning, as learning scores did not differ between groups. FSIQ ($\beta = .695$) and age ($\beta = .31$) explained 59.4% of the variance in learning outcome, $F(3, 44) = 21.43$, $p < .001$. Although entered into the regression, alerting network score (RT) was not a significant predictor ($\beta = .134$).

4.3.2 Subsample – ANT, learning and eye-tracking

This sample of 34 children (12 ASD, 22 TD) represented children for whom eye-tracking data were successfully collected for all three lessons, in addition to the other measures. Group profiles of this sample are similar to the full sample (see Table 4.5 for descriptive statistics), and the analysis here will focus on the sample in relation to their eye-tracking data. It is however important to note that the sample sizes are not equal, with nearly

Table 4.5. Subsample descriptives and group comparisons for age, IQ, learning outcome and eye tracking measures

	TD (N = 22) *M (SD)*	ASD (N = 12) *M (SD)*	Group comparisons *t*
Group profiles and outcomes			
Age in months	106.55 (11.83)	121.42 (18.08)	-2.9**
FSIQ	95.91 (10.33)	95.17 (18.34)	.15
Learning Total	34.45 (7.3)	34.83 (8.8)	-.13
Eye tracking measures			
Teacher's face looking time (%)	79.56 (15.94)	74.21 (12.21)	1.01
Background looking time (%)	15.94 (13.39)	17.77 (8.59)	-.43

** p < .01

twice as many participants in the TD group, therefore group comparisons should be interpreted with caution.

4.3.2.1 Profiles of visual attention

Means and standard deviations for the eye-tracking measures are presented by group in Table 4.5. Across all lessons, TD children engaged in looking at the screen for an average of 615.55 seconds (*SD* = 123.03). ASD children spent a similar time looking at the screen (*M* = 588.04, *SD* = 86.28), with no significant difference between groups, *t*(32) = .69, *p* = .498. As shown in Figure 4.6, both TD and ASD children looked at the teacher's face for a proportionally longer time than the background, which is to be expected as there was little visual information to look at in the background. Children with ASD looked at the teacher's face for proportionally less time on average than TD children (approx. 5% less than the TD group), although not significantly so, *t*(32) = -1.01, *p* = .321, *d* = .38. This also meant that children with ASD looked at the background for proportionally more time than TD children, *t*(32) = .43, *p* = .673, *d* = .16, though again this difference was not statistically significant.

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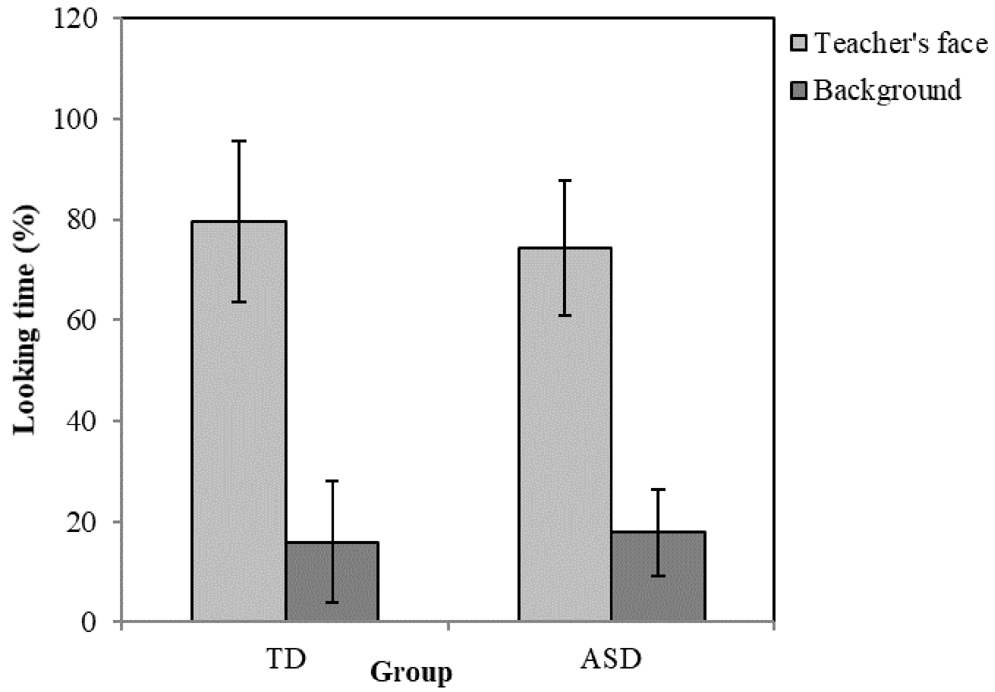


Figure 4.6. Percentage of time spent looking at each region for TD and ASD children

4.3.2.2 Correlation analyses

Correlational analyses were first conducted for all measures transdiagnostically (i.e. including both TD and ASD data), and the results of this analysis are presented in Table 4.6Scatterplots for relevant relationships are presented in Figure 4.7. When examining relationships transdiagnostically, none of the attention network scores were significantly correlated with % time looking at the teacher's face or the background, although their relationship with alerting (RT) approached significance, $r(34) = .273$, $p = .059$, $r\ (34) = -.272$, $p = .06$ respectively. With regards to learning outcome, proportionally increased looking at the teacher's face was significantly related to higher learning outcome, as was proportionally reduced looking at the background. Furthermore, there was a significant relationship between learning and alerting, in that children with better alerting achieved higher learning outcome scores. This is a relationship that had approached significance for the full sample. Neither age nor IQ were related to the eye-tracking measures.

When looking at TD children only, these relationships disappeared (see Appendix E for correlation matrix); neither of the eye-tracking measures were significantly related to learning, or the attention network scores (all r's < .26, all p's > .12). Contrastingly, age was related to both looking at the teacher's face, $r(22) = .474$, $p = .013$, and at the background, $r(22) = -.496$, $p = .009$, in that older children spent proportionally more time looking at the teacher and less at the background.

Table 4.6. Correlation matrix for subsample (N = 34)

	1	2	3	4	5	6	7	8	9	10
1. Age										
2. FSIQ	-.153									
3. Learning outcome	.219	.676***								
4. Alerting RT	.113	.128	.349*							
5. Orienting RT	.025	.158	-.178	-.177						
6. Executive RT	-.123	.211	.204	.325*	.041					
7. Alerting % errors	.115	.108	.319*	.15	-.105	.136				
8. Orienting % errors	.289*	-.151	.006	.098	.188	-.07	-.09			
9. Executive % errors	.369*	-.074	.274	.152	-.222	-.324*	.227	.09		
10. Teacher's face looking time (%)	.065	.212	.352*	.273	-.137	-.043	.192	.237	.058	
11. Background looking time (%)	-.15	-.103	-.297*	-.272	.228	.072	-.219	-.2	-.135	-.951***

All correlations are one-tailed, *p <.05, ** p <.01, *** p < .001.

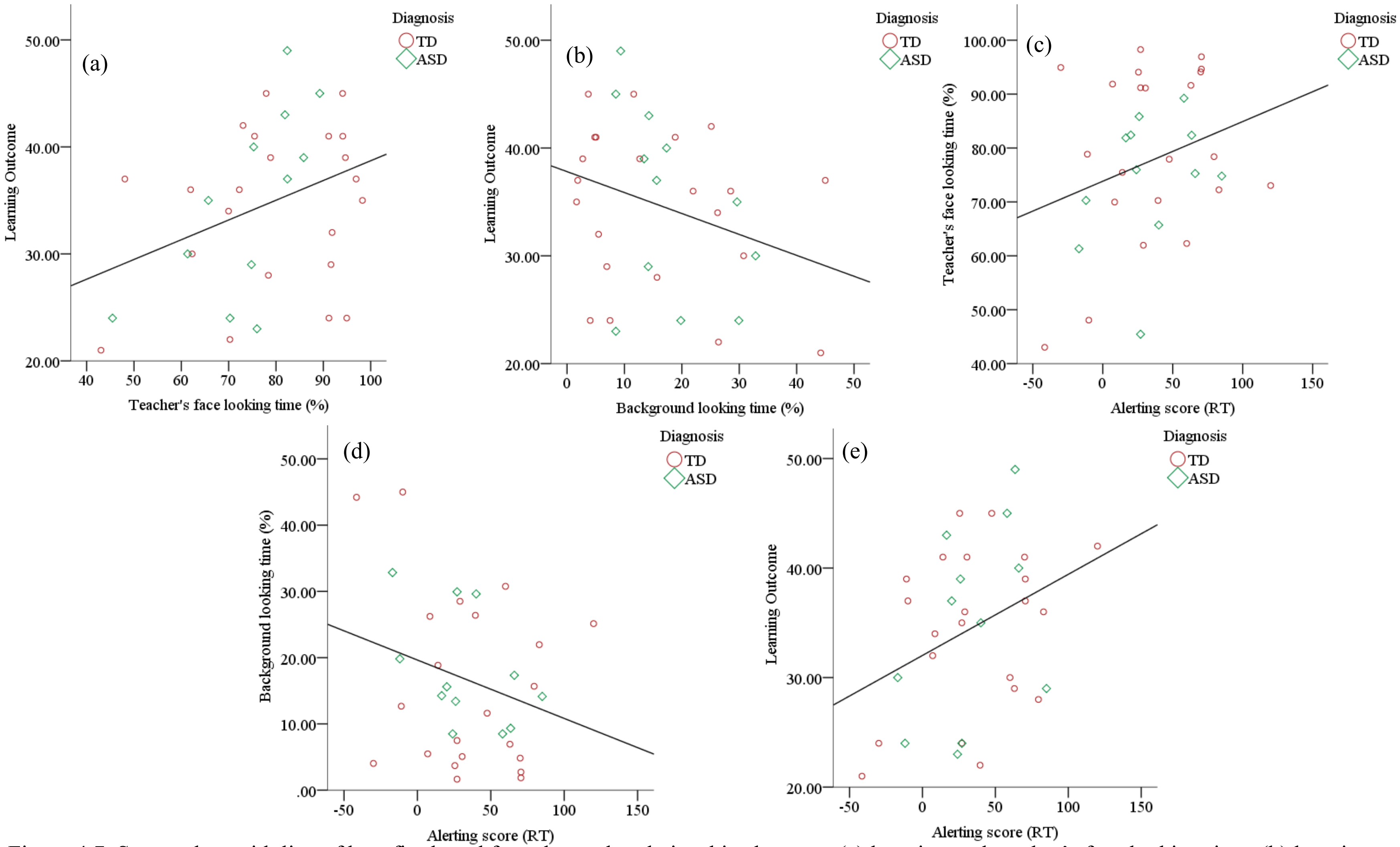


Figure 4.7. Scatterplots with line of best fit plotted for subsample relationships between (a) learning and teacher's face looking time, (b) learning and background looking time, (c) teacher's face looking time and alerting (RT), (d) background looking time and alerting (RT), and (e) learning and alerting (RT)

Correlations were also calculated for the ASD children, although it is important to note that this represents only 12 individuals (see Appendix E for correlation matrix). For these children, none of the attention measures were significantly related to attention to the teacher or background (all *r*'s < .31, all *p*'s > .07). Learning outcome was significantly related to attention to the teacher, $r(12) = .672$, $p = .008$, but interestingly not with attention to the background, $r(12) = -.435$, $p = .079$. It is possible that this was due to a power issue, as the r-value is relatively high. It can, however, only be concluded that children with ASD who spent proportionally more time looking at the teacher achieved higher learning outcomes.

4.3.2.3 Predictors of learning

A multiple hierarchical linear regression was conducted for all children (N = 34), due to the lack of power to analyse the groups independently. Diagnosis was not entered into the regression as learning outcome did not differ between the groups. The purpose of this regression was to determine predictors of learning outcome, including IQ, alerting network score (RT), and attention to the teacher. The analysis revealed that IQ ($\beta = .64$) and alerting ($\beta = .23$) accounted for 52.7% of the variance in learning outcome, $F(2, 33) = 17.25$, $p < .001$. Although significantly correlated with learning outcome, attention to the teacher's face was not a significant predictor of learning.

4.4 Full sample and subsample discussion

The aim of these studies was to investigate the relationship between attention and learning in TD and autistic children, using i) a task that tapped the multiple components of attention, ii) a direct measure of attention during a task (i.e. eye-tracking), and iii) a task that tapped classroom-based and teacher-led learning. This discussion will start by evaluating the findings in relation to group profiles and differences in learning outcomes, attention abilities, and visual attention, followed by a discussion of the findings related to relationships between the ANT data, eye-tracking data and learning outcomes. Finally, a critical discussion of the challenges of eye-tracking in autism will present the premise for the final analysis in this chapter.

4.4.1 Learning outcomes

Children performed similarly between groups in relation to the lesson worksheets. On average, autistic children scored slightly lower than TD children, but this difference was not statistically significant. This reflects the data in Hanley et al. (2017), where learning scores did not differ significantly between ASD and TD groups in the low visual distraction condition, although the ASD children did score slightly lower than the TD children. They did, however, find that children with ASD scored significantly lower than the TD children in the high visual distraction condition, suggesting that group differences only emerged when the background was visually distracting. It is therefore possible that in the current study, the middle ground visual background used was not distracting enough to create differences between groups. Indeed, it was not an aim of the current study to look at the role of visual distraction, rather the video stimuli were used to measure learning instead of to manipulate the background as in the original study. This has important implications for methodology, particularly in relation to task demands, and is an issue covered in more detail in the general discussion section of this chapter.

For TD children, learning was related to age, which was expected. Lesson scores were not standardised, therefore the older a child was the more they remembered from the lessons and the more questions they answered correctly. Age was, however, not related to learning for autistic children. This finding may be attributed to the heterogeneity of IQ in the ASD group. Indeed, IQ was strongly related to learning in both groups, and although age and IQ are related in typical development (Schaie, 1983), IQ is not necessarily stable throughout development in ASD (e.g. Dietz, Swinkels, Buitelaar, van Daalen & van Engeland, 2007; Eaves & Ho, 2004; Fisch, Simensen & Schroer, 2002; Mayes-Dickerson & Calhoun, 2003a). As a consequence, this may explain why learning in this group of children was related to IQ but not age. Equally, this emphasises that a similar relationship between IQ and learning across developmental groups may exist, which is theoretically relevant considering that some research suggests IQ is not necessarily a reliable predictor of learning in ASD (e.g. Dietz et al., 2007). It is, however, important to reflect on the findings of Chapter Three, in that IQ was not a reliable indication of academic achievement in ASD. More specifically, discrepancies existed both within and between domains that were unexpected based on the IQ of the groups. One possibility for the discrepancy between the findings here and in Chapter Three is that the WIAT-II provided standardised scores that take age into account, whereas this was not the case in the current study.

Overall these findings suggest that between groups children performed similarly between groups, which supports previous findings (Hanley et al., 2017). Importantly, as the learning measure was not standardised, this enabled an independent analysis of the relationship between age, IQ and learning. This analysis revealed that although children performed similarly between groups, the factors related to learning (i.e. age and IQ) differed. This is a finding that would be lost when using standardised measures of learning. This also highlights that other factors impacting on learning may differ between groups, demonstrating the importance of examining these relationships both transdiagnostically and between and within groups.

4.4.2 Attention abilities (full sample)

For TD children, performance on the ANT was typical in that they responded quicker and more accurately in informative conditions. Scores for alerting, orienting and executive networks were all comparable with the scores reported in studies using the same task (e.g. Pozuelos et al., 2014). Children with ASD performed typically in relation to executive attention, responding quickly and more accurately in informative conditions. In relation to alerting, they responded quicker in conditions with an alerting tone, suggesting typical performance. Their average accuracy alerting score, however, was below zero suggesting that their accuracy was consistent regardless of whether or not the alerting tone was present before the target appeared. This finding is comparable with that of Samyn et al. (2017), who found that boys with ASD made a similar percentage of errors regardless of whether or not the alerting tone was present. These findings do suggest that the alerting network may not perform typically in autistic children, but only when considering the impact upon accuracy; when considering alerting scores in relation to reaction time, performance was typical. This may be an indication of a speed-accuracy trade off, in that although they are responding quickly, this is at the expense of accuracy. As we know that children with ASD can experience sensory sensitivity (e.g. Baranek at al., 2006), it is possible that the auditory tone impacted upon their ability to complete the task. If a child was hyper-sensitive to sound (i.e. more sensitive than typical) then it is possible the sound would have been distracting and caused them to make more errors than typical in this condition. Comparatively, if a child was hypo-sensitive to sound (i.e. less sensitive than typical) it is possible that they were not using the auditory information to make appropriate decisions about the direction of the target. As this is speculative, further research investigating this notion would be beneficial.

In relation to orienting, autistic children responded quicker in trials with a valid orienting cue compared to trials with an invalid orienting cue, suggesting typical orienting ability. Similar to alerting, however, their orienting accuracy score was very close to zero, indicating very little difference in accuracy between trials with a valid or invalid orienting cue. This is a novel finding in terms of studies using the ANT; although some studies have found atypicalities in the orienting network, these have been in relation to reaction time rather than accuracy (e.g. Keehn et al., 2010, Mutreja et al., 2015). This finding does, however, correspond with other reports of atypical selective attention in autism (e.g. Burack, 1994; Renner et al., 2006).

Overall, these findings suggest alerting and orienting in ASD may be atypical, although it is important to recognise that group comparisons indicate that their overall attentional profile does not differ from TD children. It is possible that this is due to similarities between groups across most aspects of attention, meaning that some of the more subtle differences are lost in the analysis. When considering attention scores for only autistic children, the values do indicate some atypicalities in alerting and orienting ability.

4.4.3 Visual attention (subsample)

All children looked at the teacher's face for proportionally more time than at the background, which makes sense as there was little visual information to look at in the background. Furthermore, the posters that were present were not relevant to the lesson, whereas the teacher was the source of the information they had been asked to attend to. This supports the findings of Hanley et al. (2017), who found that all children spent longer looking at the teacher than at the background, regardless of how much visual information was present in the background of the video. Children did, however, spend less time looking at the teacher when more background visual information was present.

Although not significantly so, autistic children spent proportionally less time looking at the teacher's face and more time at the background compared to TD children. These patterns of visual attention are typical of children with ASD, though in most studies these group differences are significant (e.g. Hanley et al., 2014; Hanley et al., 2017; Sasson, Turner-Brown, Holtzclaw, Lam, & Bodfish, 2008). Such studies typically involve competition between social and non-social stimuli, which was not the case in the current study. This is one possible explanation for the non-significant difference between ASD and TD visual attention in the present study. Indeed, the findings presented here are comparable with those reported in Hanley et al. (2017), who found that in conditions where there was no visual information in the background of the video, there was little difference in the visual patterns of TD and ASD groups. It is possible that this is because there was very little variety of stimuli to look at, which could be compared to the findings here, a point that was raised above in relation to the impact upon learning outcomes. The differences in visual attention between groups may only emerge at a certain level of visual distraction. Indeed, a number of other studies show that the atypicality of visual attention in ASD is related to the complexity of stimuli (e.g. Chawarska, Macari, & Shic, 2012; Sasson & Touchstone, 2014; Shi et al., 2015; Speer, Cook, McMahon & Clark, 2007), in that atypicalities are less prominent with the use of simple compared to complex stimuli.

4.4.4 Relationships between visual attention, attention ability and learning

Although no clear correlational patterns between attention abilities and learning emerged when looking at groups independently from one another, when analysing the sample transdiagnostically, the relationship between alerting reaction time and learning was significant in the subsample, and approached significance in the full sample, suggesting that children with a more efficient alerting network achieved higher learning scores. This finding is comparable with previous research that has found sustained attention to be related to learning (Erickson et al., 2015; Hanley et al., 2017). It is rational to conclude from this that the ability to sustain one's attention on a task for a duration of time leads to an increased amount of information being processed, subsequently leading to a higher quality of learning. Indeed, Carroll's "time on task" hypothesis states that the more time is spent on a task, the better the learning outcome (Carroll, 1963). If a child is not able to concentrate for a duration of time, they may miss key elements of the task that are necessary for processing and understanding the information as a whole and within context. This has clear implications for learning in the classroom, particularly considering that children are expected to attend to a task for the duration of a lesson. Children with poorer sustained attention who are unable to concentrate for longer periods of time may benefit from shorter lessons or regular breaks. This is a suggestion that warrants further experimental investigation. The fact that this relationship only existed when examining correlations for the full sample, but not at the group level, may be attributed to an issue with power. Another explanation is that variability in each individual group was limited, but when looking transdiagnostically there was enough variability in alerting and learning scores for correlations to exist.

In terms of relationships between attention abilities and visual attention patterns, again, no group-based correlations emerged. Despite this, when analysing the full sample it was found that the relationship between alerting and attention to the teacher's face approached significance, as did the relationship between alerting and attention to the background. More specifically, a more efficient alerting network was associated with a larger proportion of time looking at the teacher, and less time looking at the background. As alerting arguably reflects an ability to sustain attention over time, the above associations are logical; the better a child's ability to sustain attention, the longer they are able to fixate on the appropriate target. This suggests that sustained attention was important for all children to focus their attention upon a target. As above, the fact that this relationship only existed transdiagnostically indicates possible power issues or reduced variability within diagnostic groups.

Relationships between visual attention and learning existed for the full sample and for children with ASD, in that more time spent looking at the teacher was associated with higher learning scores. These findings correspond with those of Hanley et al. (2017), who found that increased attention to the teacher was related to higher learning outcomes. This was, however, not the case for TD children, suggesting the relationship was unique to and driven by the autistic children. One possible explanation for this is that while TD children are able to attend to what the teacher is saying without looking at them, autistic children benefit more from looking at the teacher while they listen, to focus both their visual and auditory attention to the same stimuli. Indeed, in Chapter Three it was found that children with ASD who were poorer at dividing their attention between visual and auditory domains also had poorer academic achievement. Most relevantly, children with poorer divided attention had poorer reading comprehension compared to basic word reading; comprehension ability was likely recruited by the learning task in the current study since the information to be learned was verbal, as was the measure of learning (i.e. verbal questions). It may therefore be the case that children who can divide their attention between two modalities (e.g. the TD children in this study) do not need to look at the teacher to process the content, whereas those with poor divided attention must focus both visual and auditory attention upon the teacher to comprehend what she is saying. This has clear implications for learning in the classroom, a situation in which children are required to listen to information and/or instruction from the teacher. If children with poor divided attention are visually distracted, they may not process the auditory information from the teacher. Conversely, children with good divided attention may be able to direct their visual attention elsewhere while still listening to and comprehending what the teacher is saying.

When considering predictors of learning, IQ was the strongest predictor in both regression analyses, which was expected based on the existing literature. In the full sample, age was the only variable to explain additional variance in learning over and above IQ, together suggesting that children who were older and had higher IQ were more likely to have better learning outcomes. In this analysis, attention accounted for no additional variance in learning over and above age and IQ. It is likely that this is due to the fact that the relationship between alerting and learning only approached significance, and as age and IQ accounted for much of the variance in learning scores, there was little variance left for alerting to contribute to. In the subsample analysis, alerting contributed unique variance in learning over and above IQ, reinforcing the notion that the ability to sustain attention is important for learning. Although it was hypothesised that attention to the teacher's face would be predictive of learning outcome, based on the findings of Hanley et al. (2017), this was not the case, even though the two measures were correlated. One possibility is that the sample size was too small. As there was evidence to suggest relationships between alerting, visual attention and learning existed, one avenue for future investigation would be into the possibility of a mediation or moderation between the variables. It is possible that alerting efficiency is important for paying attention to the appropriate target, which then impacts upon how much is learned from the information provided by the target.

4.4.5 Challenges of completing eye-tracking in children with ASD

For almost a third of participants (N = 14), eye-tracking data could not be collected, which led to the analyses being separated into the full sample and subsample as above. Of these children unable to complete eye-tracking, the majority were autistic (N = 9). Individuals with ASD can be notoriously difficult to complete eye-tracking tasks with, particularly in relation to the calibration process, which has been reported as a reason for data loss in the ASD eye-tracking literature (e.g. Birmingham, Johnston, & Iarocci, 2017). Although body movements can be disruptive at any stage of the eye-tracking procedure, this is of particular significance at the calibration stage, during which the child must keep very still while they track a dot on the screen with their eyes. Anecdotally, many children with autism struggle with this, either in terms of keeping their body still, or in terms of tracking the calibration dot. The result of this is that most studies that use eye-tracking have smaller ASD samples compared to other studies of the same population. While this typically means the loss of some data following recruitment, more importantly it means that only a sub-group of children with autism are represented in the published data. It is therefore important to consider the possible differences and similarities in the profiles of those who can and cannot successfully complete eye-tracking tasks. To address this methodological reflection, the current study investigated differences for children with ASD for whom eye-tracking was achieved, compared to those for whom eye-tracking was not possible.

4.5 Autistic children with vs. without eye-tracking data

Following the finding that several autistic children were unable to complete eye-tracking, an additional aim of the current study was to examine the profiles of children with ASD who were unable to complete eye-tracking, compared to those for whom eye-tracking data was obtained; an important investigation of a sub-group that is typically underrepresented in the literature. Very little is known about this group of children, therefore predictions based on literature were not possible. However, as completing an eye-tracking task requires looking at a computer screen for an extended period of time, it was predicted that attention abilities would be important for this ability. Children who could not complete the eye-tracking task may therefore be expected to have poorer attention ability than those children who could. What defines samples in studies 2a and 2b is whether or not eye-tracking data was collected. Of those children for whom eye-tracking data could not be collected (N = 14), approximately two-thirds were children with ASD (N = 9). Reasons for unsuccessful capture of eye-tracking data for these participants are listed in the Method section of this chapter. To investigate possible reasons why these children had difficulties completing the eye-tracking at the cognitive level, their group profile was compared to that of children with eye-tracking data.

4.5.1 Results

The group profiles are presented in Table 4.7. As the sample sizes were unequal, and too small to conduct informative mean comparisons, effect sizes for the difference between groups on each measure were observed to assess group differences. The IQ of each group was relatively similar, with a small effect size, however children who could not be eye tracked were around 9.5 months younger than those who were with a small to medium effect size. In terms of attention abilities, groups did not differ for alerting RT, with a small effect size, however they did differ in relation to alerting accuracy with a medium to large effect size, suggesting that the alerting cue impacted children who were not eye tracked in terms of making accurate responses more than the other group. Children who were eye tracked scored higher on both orienting RT and executive RT, with medium effect sizes, suggesting that the ability to orient attention and executive attention abilities may be skills that are important for completing the eye-tracking process, although differences in accuracy for these abilities were smaller. Children who were not eye tracked scored around 5 points less on the learning outcome compared to those who were, suggesting that they learned less from the lessons. Raw SRS scores were available for 9 individuals who were eye-tracked successfully, and 5 individuals who were not. Raw scores were analysed to provide more variability within scores. Interestingly, those who did not complete the eye-tracking had higher SRS scores (medium to large effect size), suggesting that difficulties with the eye-tracking could be related to a higher severity of autistic symptoms.

4.5.2 Discussion

The comparison of group profiles of autistic children who were able to complete the eye-tracking, against those who were not, was an important step towards understanding an underrepresented group of children. Although group sizes were very small, comparisons provided some insight into possible differences in the profiles of these children. Despite having similar IQ scores, children who could not complete the eye-tracking performed worse on the lesson worksheets compared to those who could. This suggests that some factor other than general intelligence differed between these two groups, impacting on their learning outcome. It is possible that age played a role here, since those without eye tracking were slightly younger than the other group, however previous analyses for the ASD group found that age was not

Table 4.7. Comparison of ASD children with and without eye-tracking data, including effect sizes of group differences

	Eye-tracked (N = 12)	Not eye-tracked (N = 9)	Group comparison
	M (SD)	*M (SD)*	*d*
Age in months	121.42 (18.08)	112.89 (20.29)	.44
FSIQ	95.17 (18.34)	91.67 (17.04)	.19
Learning Total	34.83 (8.8)	29.89 (7.57)	.59
Alerting RT	33.08 (30.94)	33.22 (41.95)	.002
Orienting RT	79.29 (41.84)	46.44 (61.75)	.62
Executive RT	69.21 (35.71)	50.56 (26.97)	.58
Alerting Accuracy	-1.27 (6.47)	3.4 (6.59)	.72
Orienting Accuracy	2.26 (8.54)	-1.16 (6.08)	.46
Executive Accuracy	-5.9 (8.34)	-8.02 (6.39)	.29
SRS (N = 9 / 5)	105.11 (25.74)	121.2 (15.71)	.75

related to learning, therefore it is unlikely to be the source of the learning differences between the groups. One possibility is therefore the difference in attention ability between groups. Indeed, the attentional profiles of the groups appeared to differ somewhat, particularly in relation to orienting and executive reaction times, and alerting accuracy. This suggests that children who were unable to complete the eye tracking may have had less efficient attention networks, compared to those who could. Taken together with the finding, and existing literature, that attention is related to and can predict learning, this raises the possibility that these differences in attention profiles play some role in a child's ability to take part in the eye tracking component of the task. This assumption is reasonable, considering the attentional demands of completing the calibration process, and warrants further investigation in future research. Determining the specific components of attention that may be relevant here is difficult considering the very small sample sizes, heterogeneity, and the fact that comparisons were observed using effect sizes as opposed to robust statistical analyses. Furthermore, as the groups differed in some way across all three of the attention networks, it is not clear which of the underlying attentional mechanisms may have been relevant. That said, this initial analysis provides an important first step towards taking into account the heterogeneity of cognition in autism research; as discussed in detail and supported by empirical evidence in Chapter Three, the issue of measurement in the autism literature presents a challenge in terms of recognising heterogeneity in autism.

It is also important to note that groups differed in their autistic symptoms by approximately 16 points on the SRS, suggesting that children who could not be eye tracked had more severe parent-reported autistic symptoms than those who were successfully eye tracked. It is therefore possible that autism severity was related to the ability to take part in eye tracking studies. Another possibility is that autism severity was related to attention ability, in that children with more severe symptoms of autism had poorer attention, which impacted upon their ability to complete the eye-tracking. Indeed, some studies have found a relationship between SRS scores and attention (e.g. Hanley et al., 2015), therefore this is a possibility here. However, as with the other suggestions made above, it is difficult to draw solid conclusions here due to the very small sample size, which is an issue that will be discussed in the general discussion of this chapter.

Taken together, these findings are an important first step towards understanding an underrepresented group of children within the eye-tracking literature, and future research should focus on investigating the wider cognitive and behavioural profiles of this group.

4.6 General Discussion

The main strengths of this chapter are threefold. Firstly, this study used two different tasks to measure attention, both of which required little verbal comprehension from participants, which was recognised as a possible issue with the attention tasks in Chapter Three. Specifically, the ANT provided a cognitive measure of the three components of attention, while eye-tracking allowed a direct measure of attention during a task to be taken. Together, these allowed for a detailed examination of the attention profile of autistic children compared to TD children. The results of this analysis were less clear, although findings did indicate possible atypicalities in alerting and orienting accuracy. Secondly, this study used a task to measure learning that was well balanced in relation to ecological validity and experimental control. The video lessons reflected classroom based learning, more so than the standardised measures used in the previous chapter, while also maintaining experimental control. Finally, this chapter examined the cognitive profile of an underrepresented subgroup of children with ASD: individuals unable to complete the eye-tracking process. Although no firm conclusions could be drawn from the observations made regarding this subgroup, this was an important first step towards recognising a group that have previously not been researched.

4.6.1 Limitations

One limitation of this study relates to the content of the lessons, which required a certain level of comprehension ability to complete, as referred to earlier in this chapter. This was reflected in the relatively high group IQ, for example compared to the sample in Chapter Three, meaning that a less heterogeneous sample was represented in the current study. The issue of representing the heterogeneity of ASD in research was discussed in detail in Chapter Three, but this issue is also relevant here, particularly in relation to the challenges of conducting research with a heterogeneous group. For this study in particular, the implications are that although learning scores were variable in the ASD group (i.e. 19-49 out of 54), undoubtedly the sample represents a subgroup of autistic children with higher academic ability. The advantage of standardised measures is that often they begin with more simple items that are suitable for much younger children, for example, the WIAT-II can be completed with 5-year-olds, meaning that scores can be obtained even for children with significant developmental delay. By comparison, this is not possible for the learning task used in the current study. Despite this, collating the findings of studies using both types of measure provide a rounded evaluation of abilities in ASD, which is an approach adopted within the current thesis.

The small sample size in the analysis of children with vs. children without eye tracking data is also important to recognise as a limitation, particularly in relation to interpreting the findings. Due to the small sample, effect sizes were examined to observe differences between groups, as opposed to more robust statistical analyses. Clearly this does not allow for any solid conclusions to be drawn, however this study has recognised a subgroup of children that are usually underrepresented in the literature. The subgroups comparisons have allowed for an initial examination of some of the possible factors influencing the ability to complete the eye-tracking task, which highlight areas for future investigation.

As referred to previously in this chapter, it is possible that the visual background adopted in the current study was not distracting enough to incite differences in visual attention between TD and ASD groups. As the purpose of the current study was to examine the role of attention during a learning task, and not the role of visual distraction as in previous studies using the same stimuli, this is not necessarily an issue. It is, however, important to recognise the relevance of task demands upon profiles of performance within and between groups. For example, the video background in the current study had more visual information than in Hanley et al.'s (2017) "no visual distraction" background condition, but less than in the "high visual distraction" background condition. Despite this, the finding that learning scores did not differ significantly between groups suggests that the level of distraction engendered by the background in the current study was relatively comparable to that in the current study. One possibility is that this was due to the quantity of information, in that there was little to look at therefore within a short amount of time children had visually explored this information and could focus on the teacher instead. Another possibility is that the poster content in the current study was not interesting enough to engage participants for a length of time. Indeed, in Hanley et al. (2017) and Grew (2015, *unpublished)* maths and science posters were in the background. Grew (2015, *unpublished*) found that when comparing the time TD children spent looking at each poster, maths and science based posters were viewed the most often. Furthermore, autistic children are known to visually explore and perseverate on stimuli related to circumscribed interests (e.g. Sasson et al., 2011), and these posters would fall within this category. Together, this may explain the differences between the current study and previous findings. Both of these possible explanations raise an important issue with task choice, demonstrating that it is important to recognise the demands and nature of a task when interpreting findings. This is particularly relevant when integrating findings from across the literature to draw broader conclusions about attention and learning in ASD.

Finally, although one aim of this study was to use a task that reflected classroom-based learning, it is not entirely representative of a child's experience of learning in the classroom. For example, when children are learning in the classroom, other elements such as distraction from peers or the effect of teaching quality may impact upon their academic outcomes. Controlling for these factors allowed for a high level of experimental control in relation to the current research question, however, these are important aspects of the classroom environment that need to be recognised in research investigating the relationship between attention and learning. Indeed, some of these possible influencing factors will be investigated in the remaining empirical chapters of this thesis.

4.6.2 Conclusions

The current study has shown that sustained attention is transdiagnostically important for both attending to relevant information for a duration of time (i.e. looking at the teacher) and for learning more from a lesson. Furthermore, it was found that increased time visually attending to the teacher was related to improved learning outcomes for children with ASD, but not for TD children. This suggests that autistic children are more reliant on attending to the teacher visually in order to process the verbal information, whereas this is not necessarily the case for TD children. Although both sustained attention and visual attention patterns were important for learning, they did not account for a great deal of variance in learning over and above IQ and age, suggesting that other factors were at play here. Indeed, referred to above, other aspects of the classroom learning experience may influence attention and learning for children with ASD. It is important to also consider the role of these issues in the relationship between attention and learning. Furthermore, when comparing subgroups characterised by ASD children who could or could not complete the eye-tracking task, differences in ability and behaviour were found. These differences may reflect factors important for paying attention to a task (i.e. due to the demands of the eye-tracking task), therefore future research should consider these factors in more detail. The following two empirical chapters will consider some of these issues in more detail, beginning with a qualitative exploration of potential barriers and facilitators to learning for autistic children, including a focus on the role of attention. This will be followed by a chapter investigating the most prominent factors from Chapter Five and their role in the relationship between attention and academic achievement.

Chapter Five: Teachers perspectives on the factors that impact learning for pupils with autism

5.1 Introduction

The work within previous chapters has indicated that attention may be important for academic achievement in children with an ASD, and that attention skills may characterise different patterns of strengths and weaknesses in these children. It is, however, important to recognise that many other factors may be important for learning in the classroom (e.g. Keen et al., 2016); it would be beneficial to assess how important attention skills are in relation to other factors, as well as whether these factors interact with one another. Furthermore, although the research described within this thesis has started to understand the relationship between attention and learning, the factors influencing this relationship remain unknown.

In their review of the literature, Keen et al. (2016) found that a handful of studies had explored potential predictors of academic outcome, including i) environmental predictors, such as involvement in talented and gifted programmes (Assouline et al., 2012), ii) cognitive predictors, such as IQ or early speech (e.g. Mayes-Dickerson & Calhoun, 2008; Venter, Lord & Schopler, 1992), iii) behavioural predictors such as sensory processing (Ashburner et al., 2008), iv) social skills (Estes et al., 2011), and v) autism severity (Eaves & Ho, 1997). As so many individual factors have been found to predict achievement, it is important to consider the role of these factors in the relationship between attention and academic achievement. It is possible that some factors interact with one another to create an environment in which children with poorer attention are unable to access or engage with learning.

While the factors that best predict academic achievement have been considered in a range of studies using quantitative and experimental research to date, the availability of qualitative data on this issue remains limited. The advantage of the quantitative methods used so far is that they have enabled empirical manipulation and collection of data for specific factors. However, only a few factors can be considered within a single study. This makes it difficult to pinpoint the factors that best predict outcome and which should be given the most attention in future experimental research or intervention. On the other hand, qualitative research can provide rich and detailed information regarding real experiences within the classroom (that might be missed in standardised experimental testing) to guide the focus of future research. Teachers most frequently and routinely observe pupils in the context of the classroom and can therefore provide informative perspectives on the impact of different factors upon the way in which pupils in their class learn. It is also known that teachers' quantitative ratings of various aspects of behaviour, such as attentiveness or autistic symptoms, appear reliable (e.g. Constantino et al., 2007; DuPaul et al., 1998). It therefore follows that their qualitative perspectives on the experiences of autistic pupils in the classroom represent valuable insights for driving forward research, applied work, and future interventions. Indeed, some researchers have used teacher perspectives and experiences to investigate similar issues for pupils with autism, such as the challenges of teaching Physical Education (Obrusnikova & Dillon, 2011), tools to support mainstream inclusion (Able, Sreckovic, Schultz, Garwood, & Sherman, 2015; Schultz, Able, Sreckovic, & White, 2016), and the challenges faced by college students with autism (Gobbo & Shmulsky, 2014).

In addition to these studies published in peer-reviewed journals, in their book chapter Oswald, Coutinho, Johnson, Larson and Mazefsky (2008) describe interview and survey data collected as part of a larger project, and use these to discuss potential barriers to school success for individuals with Asperger's Syndrome (AS). The data they analysed for their chapter were based on parent, teacher and pupil assessment interviews and surveys regarding the implementation of a team-based approach to supporting pupils with AS. From this data set, they identified ten key barriers and challenges to school success: difficulty with social interactions, communication differences, intense interests and verbosity, cognitive rigidity, attention difficulties, sensory differences, learning difficulties, motor coordination deficits, emotional distress, and challenging behaviours. For example, they highlight examples of attention difficulties that occur in the classroom, such as this quote from a teacher, "When asked to work independently… [the child] will often gaze and not be able to focus until prompted" (p. 143, Shapiro & Accardo, 2008). They also make recommendations for addressing these barriers, for example, the use of visual schedules to keep students oriented on task during the school day. Although the authors do not offer any discussion of how these factors impact upon learning, they provide initial perspectives into possible issues for pupils on the autism spectrum in the classroom. A more detailed investigation of these issues would provide valuable insights into both the factors that affect learning in the classroom for pupils with ASD, and *how* they impact upon learning.

5.1.1 The current study

The first aim of this study was to broadly investigate the factors that teachers feel are important for learning in the classroom for pupils with an ASD. Importantly, this study considered both <u>facilitators</u> of and <u>barriers</u> to learning, to understand factors that both positively and negatively impact academic outcome. The second aim of this study was to investigate teachers' perspectives on the role of attention in learning for pupils with autism, and to examine the interactions between attention and other factors that may impact upon learning. To achieve these aims, semi-structured interviews were conducted with teachers, a methodology that was chosen in order to obtain rich qualitative data for analysis. As autistic primary school pupils can attend either mainstream schools or access Special Educational Needs (SEN) provision, teachers from a range of school provisions were interviewed for a rounded insight into their perspectives on facilitators and barriers to learning for pupils with autism.

5.2 Method

5.2.1 Participants

Ten teachers (9 female) of pupils with autism took part in the study; three teachers worked in mainstream primary schools, three worked in mainstream primary schools with SEN provision, and four worked in SEN schools. The pupils with autism that the teachers worked with were therefore mainly aged between 5 and 11 years, although this ranged up to age 16 years for one of the SEN teachers. The characteristics of the sample are presented in Table 5.1. The teaching experiences of the teachers varied; overall number of years teaching ranged from 1 to 20 years, and the number of years supporting or teaching children with autism ranged from 5 to 26 years. At the time of interview, participants were currently teaching or supporting between 1 and 10 children with autism, and therefore these were all teachers who were currently actively engaged with supporting pupils with autism. The sample represents perspectives from a range of teachers, both in relation to their experience and the school environment they taught in. Most participants were currently working as a class teacher (N = 7), but two were dedicated Special Educational Needs Co-ordinators (SENCOs) with reduced class teaching responsibilities, and one was a Higher Level Teaching Assistant (HLTA). One of the class teachers was currently completing their teaching qualification, but all other teachers (with the exception of the HLTA) were fully qualified. Participants were recruited via social media (i.e. Facebook and Twitter), and through the research team's existing contacts.

5.2.2 Semi-structured interview

The semi-structured interview (see Appendix F) comprised three parts: (1) demographics and teaching background, (2) barriers to and facilitators of learning in the classroom, and (3) attention and learning in the classroom. Part 1 included questions about how long the participant had been teaching, whether they had received any autism training, how long they had been teaching or supporting a pupil with autism, and details of how teaching is facilitated within the classroom (i.e. class size, staff ratios). Part 2 focused on questions about what teachers felt were the biggest barriers to and facilitators of learning,

Table 5.1. Teacher demographics

Teacher	School Type	Current role	Years teaching overall	Years supporting autistic pupils	Number of autistic pupils currently teaching/supporting	Age range of pupils taught (years)
1	Mainstream with SEN	SENCO	20	20	10	5-11
2	SEN	Class teacher	11	7	8	5-16
3	Mainstream with SEN	HLTA	N/A	26	1	5-11
4	SEN	Class teacher	10	10	4	7-10
5	Mainstream with SEN	Class teacher	14	9	7	5-9
6	Mainstream	Class teacher	5	5	3	5-6
7	SEN	Class teacher	3.5	6	7	5-8
8	Mainstream	SENCO	15	15	6	8-9
9	Mainstream	Class teacher/SENCO	12	12	2	4-5
10	SEN	Class teacher (completing teaching qualification)	1	5	5	5-16

and what their impact was upon learning, including questions about whether teachers felt the factors were specific to autism or not. The purpose of asking both about barriers and facilitators to learning was to encourage teachers to think both about factors that positively and negatively impact on behaviour. The focus of Part 3 was upon the role of attention in the classroom for autistic children, including questions about whether attention skills are important for learning, what kind of factors are the most distracting, and how this impacts on learning. Participants were interviewed individually, either in their school or at the university, and lasted between 30 and 50 minutes. The interviews were audio recorded and later transcribed.

5.2.3 Qualitative data analysis

Data-driven thematic analysis (Braun & Clarke, 2006) was used to analyse the transcripts. Thematic analysis is a method unconnected to any ontological or epistemological frameworks that is used for "identifying, analysing and reporting patterns within data" (p.79, Braun & Clarke, 2006). This qualitative data analysis technique was chosen for a number of reasons. First, it allows for a data-driven approach to analysis, as opposed to theory-driven methods such as content analysis or discourse analysis (Braun & Clarke, 2006). Secondly, and related to this first strength, it is a flexible approach that subsequently provides a rich and detailed account from the perspective of participants (Nowell, Norris, White & Moules, 2017). It is, however, also important to recognise disadvantages of thematic analysis. One prominent issue with this analysis is the potential for themes to be created based upon the interview schedule (e.g. theme of "barriers to learning"). This can, however, be avoided in the approach to coding, for example, by analysing the data based on sub-sections of the interview (see below). Another potential limitation of thematic analysis is that it can result in the loss of narrative within data sources, as findings are categorised across all participants. It is therefore important to recognise the context of particular codes, for example, which section of the interview particular themes emerged from. The strengths and limitations of this method will be discussed in more detail in the discussion section of this chapter.

In the first stage of the thematic analysis, the author reviewed the transcripts and identified codes within the data. As this was an exploratory analysis, driven by data not theory, bottom-up inductive coding was used to analyse the content of the transcripts, meaning that codes were not predefined; the researcher created a new code each time a new topic or reference was made in the transcript, which could then be attached to any subsequent references across the data set. In the second stage, patterns between codes were identified and grouped into themes. Once these themes were established, codes were returned to and reassessed and/or refined within the context of the themes. Finally, themes and sub-themes were defined. Data from 20% of participants was double coded by an independent researcher, and 100% inter-rater agreement was obtained.

As the interview had two separate sections, each with a different focus, the data from each section was analysed separately, resulting in two distinct but related analyses. Linked to the point about limitations of thematic analysis made above, an additional reason for analysing the data set in this way was to ensure that the themes that emerged were not merely iterations of the interview questions. Therefore, the data will be discussed in two sections; Study 3a will focus on responses to Part 2 of the interview, relating to general factors that impact on learning (barriers and facilitators) and Study 3b will focus on responses specific to Part 3 of the interview, related to attention skills and the impact upon learning.

5.3 Results

It is important to note that all teachers referenced the individual differences seen between children with autism, therefore although they were asked to talk about autistic children in general, they recognised that individual differences existed and noted that an important factor for one child may not be important for another child. This is relevant to the thesis as a whole, and an issue that will be returned to in the chapter discussion.

5.3.1 Study 3a: Factors that impact on learning

Although teachers were asked about barriers and facilitators of learning in two separate questions of the interview, there was significant overlap with regards to what teachers discussed in response to these questions. For example, the same factors impacting on learning could be discussed both in terms of barrier and a facilitator of learning (e.g. the presence of particular facilities/equipment was considered a facilitator, but the absence of it was a barrier). As a result, the analysis focused on identifying factors that impacted on learning, recognising that these could be related to learning in either a negative or positive manner.

Responses from teachers on the whole fit into five main themes: i) pupil's behaviours and abilities (i.e. factors related to the child's behaviour, cognition or personality), ii) pedagogy (i.e. factors related to the practice of education), iii) factors external to the school (e.g. funding, parents), iv) the school and/or classroom resources (e.g. classroom size, facilities) and v) teacher skills and qualities (e.g. training, trust and relationships). The factors that were coded within each of these sub-themes are presented in Table 5.2. In the following results section, each of the themes will be described in turn, accompanied by examples. The purpose of this is to illustrate the themes that were mentioned within context.

Table 5.2. Themes and sub-themes regarding factors that impact on learning

Themes	Sub-themes	Example quotes
Pupil’s behaviours and abilities	Attention Communication Anxiety Motor skills Self confidence Sensory issues Social skills Striving for perfection	“it’s that kind of wasting transition period that's when they start getting upset or anxious or mischievous and start throwing things because it's more fun than just sitting there, you know, and they haven't got the attention to carry on with their job” “they'll quite often just refuse to do something before they've even tried, or refuse to learn a new skill or activity because they're just worried about failing, or they're worried about if their peer can do it better than they can”
Pedagogy	Engaging in learning Individual centred approach to teaching Learning in context / with practical purpose Structure, planning and transitions Understanding of academic purpose	“some of the children here would understand why they would still have to endure the boring topic because they understand that they’ve got their targets to meet” “it's important that they know what's expected of them and we can facilitate that by just giving it in a very clear, structured way each and every time”
Receiving a diagnosis	Funding Parent attitudes	“because we didn't have a support plan or any money coming in I couldn't give her anything more than the TA who was usually my class and that wasn't all the time so she spent a lot of time distressed, you know, not accessing anything”
School/classroom resources	Access to facilities or equipment Class size and ratios Tools to support learning	“I've had children who if they're sat with a weighted blanket on their knee can sit on a chair and do a job at a table but without that can't and needs to be up and moving”
Teacher skills and qualities	Autism training / awareness Quality of teaching Trust and relationships Understanding the child	“maybe that’s why they’ve got such a good relationship in that the children appreciate that we’re trying to help them … on the whole, there’s just that appreciation of staff and, cause we love them so much”

5.3.1.1 Pupil behaviours and abilities

All teachers (N = 10) spoke about factors they felt impacted on learning that were related to the pupil's behaviour, abilities or experience. Within this, eight sub-themes emerged, and the most regularly mentioned by teachers were communication (N = 5), anxiety (N = 9) and sensory issues (N = 10). These were therefore issues prevalent across school provision.

Five teachers, four from SEN schools and one from a mainstream school, reported that a pupil's ability to communicate effectively was important for accessing learning, both in terms of receptive and expressive communication. Teachers described the importance of communication as a gateway to accessing learning, in that if a child is not able to effectively communicate or understand what is being asked of them by the teacher, and the impact of this is they are not able to engage in the learning process. Equally, poor communication could lead to frustration and subsequently cause disengagement from the learning:

> *"Communication in general ... it's a huge thing for education. If you can't understand or be understood, how on earth are you going to learn academically or achieve the outcomes that I'm wanting?"* - Teacher 7

> *"the most obvious difficulty that they encounter on a day to day basis is communicating effectively ... and that becomes really, really frustrating really, really quickly for our children. They switch off, the learning just doesn't happen if they can't access whatever communication is going on"* - Teacher 2

Nearly all of the teachers (N = 9) described anxiety as having an impact on the learning experiences of children with autism. The consensus generally seemed to be that if a child is experiencing anxiety, it becomes all encompassing so they can't focus on their work:

> *"their anxiety levels go so up so high they can't think"* - Teacher 1

> *"some of our what you would probably call high functioning autistic children have the highest levels of anxiety ... it can be little things like they want a drink but the drink's near the sink ... so that stops them from doing any of the learning because they're so focused on getting their water bottle"* - Teacher 9

All teachers (N = 10) described sensory issues as having an impact on the learning experience of children with autism, which is unsurprising considering the prevalence of sensory processing issues across the autism spectrum. Teachers described the impact of sensory issues upon learning, which was usually related to an inability to focus or time taken from the day to support their sensory needs:

> *"(he) flaps a lot, gets out of his seat, makes noises, traces things, and that issue with sensory processing has a direct impact on his education because if I'm standing teaching, he literally cannot concentrate on me"* - Teacher 7

> *"if it's dealt with as much as it can be then you're gonna limit some of the anxiety and some of the behaviours that are associated with it. If you don't then you're gonna get those behaviours that can be challenging, that can be misunderstood, that can be a true barrier to learning because that child just physically can't be in that space… and potentially if they react particularly strongly and particularly challengingly and they act with violence towards other children … they'll have exclusions too"* - Teacher 8

5.3.1.2 Pedagogy

The process and structure of learning was a key theme, which included sub-themes that related to engagement and the importance of structure within the school day for autistic pupils. Nine teachers across types of school provision described the importance of structure and this was generally linked to anxiety; a lack of structure can be anxiety inducing and therefore distracting for pupils with autism, thus providing structure allows pupils to accept what's coming next and focus on the task at hand:

> *"it helps them to structure how their day is going to go, so they then can sit down and concentrate on what's going on rather than being anxious or kind of not knowing what's going on"* - Teacher 6

> *"it (visual timetable) literally helps them get through their day… it allows them to see what's happening next and to cope with that and then get through their day and do what we're asking them to do … (and without that there would be) a lot of anxiety and looking out the window for when mom's coming and trying to abscond"* - Teacher 4

Two teachers, both from SEN schools, also talked about the importance of engaging pupils within the learning experience, and that providing a clear purpose to the task could increase engagement:

> *"motivating and engaging them in a task that means something to them is really important, I think making it functional so that it's going to be useful for them in their*

day to day life. If they can't see a purpose to it or they can't see a reason as to why they are doing a task it becomes completely meaningless" - Teacher 2

5.3.1.3 Receiving a diagnosis

Two teachers from mainstream schools spoke about factors related to the process of receiving a diagnosis that can have an impact on a pupil's learning. This theme related to receiving funding that would not otherwise be available, and parents' attitudes towards an autism diagnosis, which seemed to be interconnected:

> *"I've had a little girl who got diagnosed once she was in year two but all the way through reception they tried to get mum on board and mum (said) nope no no there's no issue … she came to my class and she wasn't able to access anything and because we didn't have a support plan or any money coming in I couldn't give her anything more than the TA who was usually my class and that wasn't all the time so she spent a lot of time distressed you know not accessing anything because I didn't have anyone to work with her"* - Teacher 6

As this was a much less prominent theme, endorsed by only two teachers, both of whom were from mainstream schools, it may be the case that this is a theme specific to pupils in a mainstream setting. Furthermore, this was an influence external to schooling that although two teachers deemed important would, to an extent, be out of the school's control.

5.3.1.4 School and classroom resources

A theme surrounding the school and classroom resources emerged, which referred to the number of children and staff within a class, and the facilities and equipment available within the school. This discourse was mostly led by mainstream teachers, most likely because of the lack of these resources means the impact is more prominent in mainstream schools. Four teachers (mainstream N = 3, SEN N = 1) referred to the ratio of children to staff within a class, and how this can impact on the learning experience of the pupils with autism in the class:

> *"it's alright knowing that sitting next to someone and holding their arm is gonna help them through a maths lesson but if you've got 30 other kids and you've got other children with SEND needs … the size of your class can make that (providing support) an impossible thing as a teacher"* - Teacher 8

> *"without the extra adults I have I wouldn't they wouldn't make anywhere near as much progress 'cause I just wouldn't be able to spend the time I need to with them"* - Teacher 6

Three teachers, two from mainstream schools and one from SEN, spoke about the impact of having access to appropriate facilities and equipment, in that it can allow children to access learning that they are otherwise too distracted to access:

> *"they (equipment) might help the children to feel calmer or to do their jobs which otherwise they would be too distracted to do, or to listen in carpet time or to access small group work whereas they might need to be one to one other wise…things like the weighted blankets I've had children who if they're sat with a weighted blanket on their knee can sit on a chair and do a job at a table but without that can't and needs to be up and moving"* - Teacher 6

5.3.1.5 Teacher skills and qualities

Eight teachers commented on the importance of aspects relevant to the teacher, which included understanding autism (N = 3) and building relationships with the child (N = 4). This theme and sub-themes were present across teachers from all types of school provision. Understanding both the nature of autism, but also what it means for that individual child, was considered to be important in order for a teacher to provide the pupil with appropriate support:

> *"you need an understanding of what ASD is but you also need an understanding of what that child's profile is…so what's the sensory needs what are their strengths and weaknesses as an individual child …and (if) you don't match your teaching to how that child learns … then it's likely to have an emotional and anxiety effect on that child and therefore they could shut down or they might be disruptive in their behaviour and what you're not getting is that place where any academic learning can happen"* - Teacher 8

5.3.1.6 Study 3a: Discussion

Teachers discussed factors that impact on learning for children with autism over a range of different areas, highlighting the breadth of potential challenges to accessing learning that are faced by pupils with autism, as well as a wealth of possible ways to overcome these barriers and support pupils to learn in the primary school classroom. Some of these findings corroborate with existing qualitative research (Able et al., 2014; Oswald et al., 2008) and experimental work (Ashburner et al., 2008; Miller et al., 2017), while other findings are believed to be novel insights gained from this study and research approach. These will be discussed in detail below. The teacher interviews were therefore highly informative and valuable in terms of identifying areas that require further investigation and/or attention in relation to making appropriate school and classroom adaptations. Some themes were present mostly within a single school provision type, while other issues were ubiquitous; these issues will be discussed below in relation to each theme.

Pupils' own behaviour and abilities were the most regularly discussed issues, mentioned by all teachers as having an impact on learning, which supports existing experimental work. Previous research has found communication (Miller et al., 2017), anxiety (Oswald et al., 2016), sensory processing (Ashburner et al., 2008) and social skills (Estes et al., 2011) all to be related to academic outcomes in ASD, which aligns with the issues reported by teachers in the current interviews. Most of these themes were also issues raised by Oswald et al. (2008), who found communication, social skills, attention difficulties, sensory differences, motor co-ordination and emotional distress (e.g. anxiety) to be barriers to learning for students with AS. The novel contribution that the present study adds, however, is the teacher accounts of how these factors can impact upon learning for autistic children within the context of daily school life.

With regards to how these aspects of a pupil's behaviour or cognitive abilities impacted upon learning, attention appeared to be a mediating factor in some instances; for example, a child experiencing anxiety could be so distracted by their worries that they are unable to focus their attention on a task, impacting on their learning outcomes. This concept was particularly prominent in descriptions surrounding anxiety and sensory issues, but was present throughout the discourse. Relationships between behaviour/cognition and other factors also existed, for example, some teachers spoke about a lack of structure causing anxiety in children with autism, leading to distraction and reduced engagement with the learning material. These are themes that will be returned to in Study 3b that focuses specifically on attention, however, it is important to recognise that the issue of attention was raised even when teachers were not specifically probed or directly asked about it.

The theory and practice of education was also relevant in terms of the impact upon learning for pupils with autism, mentioned by all teachers. Teachers spoke about making learning materials interesting and/or functional to engage children, ensuring the pupils have clear objectives and understand the purpose of tasks. Providing structure to both the day and individual lessons so that pupils could plan ahead was also considered to be important, which is a strategy previously recognised within the literature in relation to autism (e.g. Helps, Newsom-Davis & Callias, 1999; Humphrey, 2008). It is important to note, however, that three teachers did recognise that some of these approaches to teaching are not necessarily specific to autism in that many children could benefit from them. That said, it may be the case that these factors are more exaggerated in importance for autistic children. It is well established that a preference or need for routine is a core feature of autism (e.g. "inflexible adherence to routines" - APA, 2013), and therefore the lack of structure could conceivably have a negative impact upon the learning experience of these children. Furthermore, teachers referred to the link between a lack of structure and the presence of anxiety, as mentioned above, highlighting one potential negative outcome. One possibility is that this is related to intolerance of uncertainty (IU), which reflects anxiety surrounding uncertain or ambiguous situations, and has been found to be related to restrictive and repetitive behaviours in autism (Wigham, Rodgers, South, McConachie & Freeston, 2015). Taken together, this may mean that although all children can experience positive benefits from the presence of structure, in autism the lack of structure can lead to exaggerated negative outcomes.

More practical aspects such as obtaining a diagnosis and school/classroom resources were also mentioned within the interviews, showing that factors impacting on learning can even extend to variables outside of the control of teachers. It was only mainstream teachers who discussed the process of receiving a diagnosis as having an impact upon the pupil's learning experience. They explained that without a diagnosis, the school could not receive funding for additional support such as dedicated teaching assistants or SEN resources. Previous research has found the lack of SEN resources to be an issue reported by parents. Lindsay, Ricketts, Peacey, Dockrell and Charman (2016) interviewed parents of 53 children with ASD, and found that parents of children attending mainstream schools with SEN provision reported higher overall satisfaction with the school provision and that their child's needs were being met, compared with parents of children in mainstream schools with no SEN provision. Furthermore, Van Herwegen, Ashworth and Palikara (2018) conducted a survey of parent's views on SEN provision with parents of children with ASD, Williams Syndrome (WS) and Down Syndrome (DS) and found that 48% of parents of autistic children reported that they felt the SEN needs of their child were not being met. Children attending SEN schools, or schools with a SEN provision, are likely to already have a diagnosis and/or funding available, making this less of an issue from SEN teacher's perspective. Linked to this, class size and pupil to staff ratios were also only described as having an impact on learning by teachers in mainstream schools. Van Herwegen et al. (2018) also found that pupils with ASD were less likely to receive one-to-one support compared to pupils with WS or DS, showing the potential lack of support for these pupils. It is likely that SEN schools have higher staff to pupil ratios, and mainstream schools with SEN provision have access to smaller group or one-to-one learning opportunities that mainstream schools may not have, which links back to the issue of funding.

Finally, the qualities and skills of the teacher were considered to be a factor with potential to impact on the learning experiences of pupils with autism. This related not only to the teacher's understanding of autism, but their understanding of what an autism diagnosis meant for the individual child, which is a pre-requisite for building trust and good relationships. This is a sub-theme that has also emerged in similar work; Able et al. (2014) conducted teacher focus groups on the topic of facilitating inclusion for autistic students. They reported that teachers expressed the importance of understanding autism and the learning needs of each individual child in order to effectively support them within an inclusive learning environment. Van Herwegen and colleagues (2018) also reported that in their online survey, parents of children with ASD were less satisfied with the one-to-one support their child received compared to parents of children with WS or DS. Some of these parents commented that they felt staff did not understand their child and/or their needs, showing the importance of these issues not only between studies but across informants.

Overall, the range of factors that teachers emphasised as having an impact on learning for autistic pupils was vast, highlighting key areas for further investigation. Analysis of the teachers' discourse indicated the existence of complex relationships that impact upon learning for children with autism, showing that there are many layers to the story of how to support these pupils to achieve their best at school. Unravelling this with the support of empirical work is an important next step prior to devising interventions.

5.2.2 Study 3b: The relationship between attention and learning

The final section of the interview focused on teachers' views of the relationship between attention and learning. Transcripts were analysed using thematic analysis in order to identify themes within the discourse regarding this relationship. Four key themes emerged from this section of the interview, these being: attention ability, psychopathologies, classroom environment and engagement. The themes and sub-themes are presented in Table 5.3, and Figure 5.1 shows the thematic map.

5.2.2.1 Attention ability

Seven teachers spoke about the attention abilities of children with autism, and specifically mentioned issues with attention span (N = 3), and the ability to divide attention between two modalities (N = 4). In relation to attention span, three teachers from SEN schools commented on pupils not being able to focus for longer periods of time:

> *"these children have a very short attention span, a very short amount of time in which they can concentrate … there is absolutely no point in trying to teach them for 15*

Table 5.3. Themes and sub-themes regarding attention and learning (Study 3b)

Themes	Sub-themes	Example quotes
Attention ability	Short attention span Divided attention	"they don't really have a very good attention span at all, so it might be that they can only do it in 10 minutes at a time" "I now know that they are listening to me even though they're not looking or if they're fiddling because if I ask them a question, they can answer it or they can tell me some of the things when we get back to the table"
Psychopathologies	Anxiety Sensory processing Restricted interests	"sometimes the children who can't filter out the additional noise that's going on in the classroom … they're unable to concentrate, they're unable to apply their knowledge … and you can't apply yourself when you're at a heightened state of anxiety"
Classroom environment	Visuals Other children Class size Staff ratios	"I guess the visual side of things for some children there's a lot to look at and you know they are big bright classrooms crammed full of things" "so they can sometimes be easily distracted, and, and can be very concerned with what other children are doing"
Engagement	Interest in topic Communication Engaging learning environment Movement break Prompting Structure to learning	"I think making it easy and accessible and just what's happening now what's happening next is probably as much as some of our kids need" "you're more able to get attention if they know … how long they've got to have attention for, what they get at the end of it type thing so again it comes down to being clear with what you want them to do and what you want them to attend to"

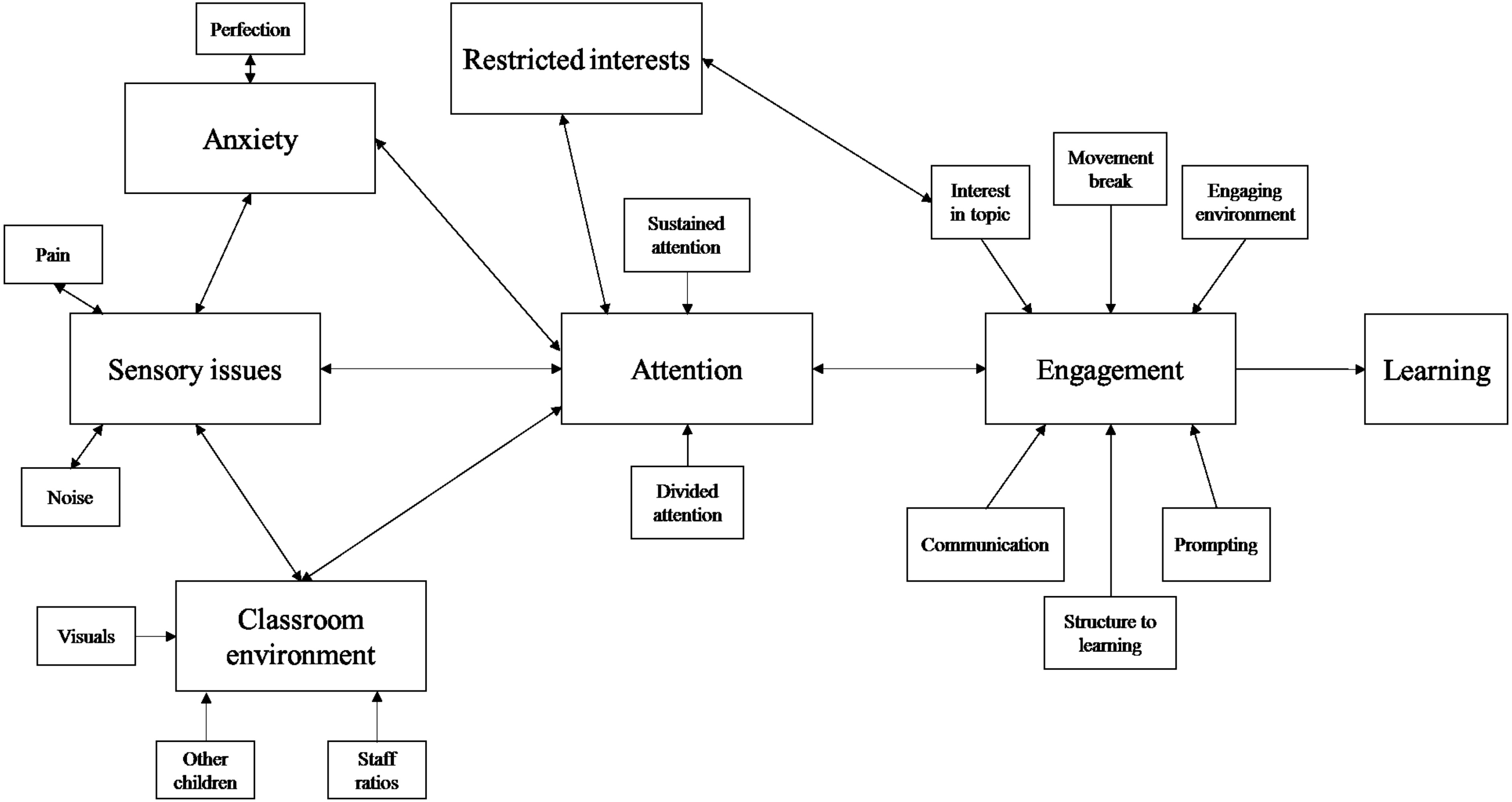


Figure 5.1. Visualisation of Study 3b themes and their relationships

minutes because after five minutes they've zoned out they're thinking about something else, they're doing something else and they are not learning" - Teacher 2

Four teachers also mentioned divided attention, specifically between auditory and visual domains. This was mentioned in the context of attending to the teacher, and that some children may not be looking at the teacher while they speak, but would still be listening and processing the auditory information, or vice versa:

"I call them back seat learners where you don't think that they're paying attention because they might be fidgeting with something under their desk but you ask them to repeat what you've said or you ask them a question about what you've said and they can give you an answer because they were actually attending to what you're saying" - Teacher 4

"I now know that they are listening to me even though they're not looking or if they're fiddling because I know they are because if I ask them a question they can answer it" - Teacher 6

"even if they look like they're paying attention they're concentrating you never know what they're thinking about the same time" - Teacher 9

This seemed to be relevant from the perspective of teachers across the range of school provisions, as teachers from mainstream (N = 2), mainstream with SEN provision (N = 1) and SEN schools (N = 1) all referred to this phenomenon. Importantly, within the overall discourse it was emphasised that there are individual differences with regards to their attention abilities:

"if the children are bright enough and they are interested ... they can listen, but for some of the other children they've missed half the conversation because they're looking around or they're worried about something else" - Teacher 9

5.2.2.2 Psychopathologies

Teachers also commonly spoke about different aspects of psychopathology (N = 9) that were related to attention, which included anxiety (N = 7), sensory processing (N = 6) and restricted interests (N = 4); all of which are common experiences of individuals on the autism spectrum (e.g. Ben-Sasson et al., 2009; Weisbrot, Gadow, DeVincent, & Pomeroy, 2005). Anxiety was described as being related to attention in that if a child was experiencing anxiety, it would be difficult for them to focus on the task at hand, which would therefore impact on learning time:

> *"attention can also be very strongly linked to anxieties as well and so if they're worrying about something else it's difficult to focus on what they're doing at that time"* - Teacher 8

> *"they're unable to concentrate, they're unable to apply their knowledge even if they do know what they're doing, they're distracted and they're emotional, and you can't you can't apply yourself when you're at a heightened state of anxiety"* - Teacher 9

Sensory experiences of children with autism were also discussed by six teachers in relation to attention and learning. Teachers described how sensory aspects of the environment can be difficult to ignore, and that this can distract children from their work, impacting on their learning output. Noise was the most frequently mentioned sensory distraction (N = 6), but light (N = 2) and pain (N = 2) were also mentioned.

> *"sometimes the children can't filter out the additional noise that's going on in the classroom, you know the monitors make a big loud noise, the screens are so bright"* - Teacher 9

> *"it becomes all encompassing ... and if (they) do manage to get anything done it wouldn't be the best- there wouldn't have been much point"* - Teacher 1

Finally, four teachers mentioned how the restricted interests of pupils with autism can impact on their attention and subsequently upon learning. Children can often be fixated on their own personal interest, leading to an internal distraction where their attention is focused upon their own thoughts. This impacts on learning in that they are spending more time focusing on their own interests rather than upon the learning experience:

> *"I had a boy two years ago that Pokémon was in his head ... the knowledge about things is so big, it's almost like they can't leave it, they bring it with them into lessons"* - Teacher 1

> *"two of them actually really love reading and then they just get so engrossed in doing that reading and then they won't stop you know when you've asked ... so if it's something they're interested in they can get really focused on it to the opposite extreme"* - Teacher 5

5.2.2.3 Classroom environment

Another theme that emerged from the teachers' discourse was the classroom environment, and its role in the relationship between attention and learning. Aspects of the environment, such as other children in the class (N = 5), staff ratios (N = 2) and the visual environment (N = 3) were all mentioned. Five teachers spoke about how the other children in the class can impact on attention for children with autism, as this can cause them to be distracted:

> *"they need to be able to pay attention with a lot of distractions if they're in the classroom, just from other children because the children are moving about other children are talking or have lost their pencil, or are doing another job, so there's a lot of distractions in the classroom"* - Teacher 6

This issue of distraction by other children could be related to class sizes, and subsequently to the theme of staff ratios, in that if there were too few staff in relation to the number of children who needed support, this could impact negatively on their learning experience. Two teachers, both working within mainstream schools, described how some children would need dedicated support from a staff member in order to maintain their attention on a task:

> *"if you literally if you sit with her like that she will do the whole worksheet, but if you turn (away) she'll draw a big picture ... so of course then she's not practicing the skills or whatever that I've put down for her ... it's almost like that pressure to concentrate whereas as soon as my attentions elsewhere she can't then concentrate and she doesn't wanna do the job so she's not going to"* - Teacher 6

Three teachers, from mainstream (N = 2) and mainstream with SEN provision (N = 1), mentioned how the visual environment, including visual displays and windows, can also be a distraction for pupils with autism when they are working in the classroom:

> *"we've got a lot of windows in my class so if there's something going on outside and sometimes it's windy like the leaves blowing and that's that can all be distracting ... it can just distract them from doing their best not getting enough work done"* - Teacher 5

> *"after some training I've actually taken a lot of the visuals down to try and calm things down a bit so I have nothing around the board, well I have my date and that's it, but I used to have like all letters and you know sounds and stuff ... (now) my displays are a lot calmer which seems to help all children but particularly those who have autism"* - Teacher 6

5.2.2.4 Engagement

The final theme that emerged from the data related to the importance of engagement in the relationship between attention and learning, mentioned by all teachers (N = 10). Two teachers reported that having an interest in a topic was a successful way to engage pupils, drawing their attention to the learning task:

> *"having it as something that's of interest to them so you wouldn't give someone who's interested in Mario and hates animals something do with animals, you would look at what they're interested in … (then) they can get quite excited about what they're doing, so it means that they're more likely to focus for longer"* - Teacher 10

One teacher from an SEN school also spoke about taking children out of the physical classroom for some lessons, and that this engaged them in the learning in a different way, impacting on their ability to concentrate for longer periods of time:

> *"when we are outdoors … then they can concentrate for a much longer period of time and that would come back to engagement because I suppose … their environment is constantly changing as we're walking along and there's different things to see and so they can concentrate on each of those things for a little while and it's not having to maintain the attention of looking at the board for 15 minutes so I think that they're definitely more engaged and can hold attention for a lot longer when they're out of the classroom"* - Teacher 7

Four teachers (mainstream N = 2; mainstream with SEN N = 2) also mentioned the significance of prompting the pupil, either by using their name or directing their attention back to the task in another way, and that without this prompt, some children would struggle to stay on task and complete their work:

> *"if she does drift off its then bringing her back again. She would not be able to solve a problem like not having a pencil, even finding the right page in a book, those kind of things I have to do for her … so there just has to be that constant prompt (and) she does alright"* - Teacher 6

Finally, six teachers talked about the use of structure to keep pupils engaged with their learning, for example building in reward time to the learning routine:

"if they do drift off you can focus on back on what you want them to do before they can have their reward … they've got to know what they've got to do and what's in it for them at the end, and then they're more likely to keep attention" - Teacher 1

This theme links to similar findings from Study 3a, in which teachers described how structure was important for pupils with autism so they knew what was coming next, and that this could reduce their anxiety about uncertainty.

5.2.2.5 Study 3b: Discussion

Overall, teachers described attention as having a direct impact on learning, as well as being a mediating factor between other factors and learning, which resulted in four interconnected key themes emerging from the analysis. Presented in Figure 5.1 is a visual depiction of the themes that emerged from the analysis, and the interplay between them, which will be discussed in detail below. This was created using the themes and sub-themes identified from the thematic analysis.

To understand the wider story that emerged from the analysis, it is important to begin by discussing the underlying attentional atypicalities in autistic pupils that teachers described. Three teachers commented on the fact that some pupils with autism have a "*very short attention span"*, and that this impacts on the length of time they can engage with learning. This resonates with the findings related to empirically measured alerting ability within Chapter Four of this thesis, as well as the wider literature (e.g. Samyn et al., 2017), although in many studies, sustained attention ability has been reported as comparable to TD populations (e.g. May et al., 2013). It is possible that this short attention span actually reflects atypicalities in selective attention, which has been found to be atypical in ASD both within the literature (Keehn et al., 2010; Mutreja et al., 2015; Renner et al., 2006) and within Chapter Three of this thesis in relation to performance measured by the TEA-Ch. In the context of the classroom, it may be that when a child is distracted from their work, they are unable to reorient their attention to the task, reflected in the "*very short attention span*" reported by teachers. Teachers also described strategies for managing this issue; they referred to reducing the length of tasks, or breaking down work into smaller sections to allow pupils to maintain focus, resulting in them spending more time engaged in learning overall. This suggests that although the ability to maintain attention may be relatively poorer for some pupils with autism, there are effective strategies for managing this in the classroom. In addition, this description of attention in autism was only present in interviews with SEN teachers. It is therefore possible that this observation regarding short attention span is more prevalent in autistic children attending SEN schools, and subsequently could be related to the presence of more complex needs.

In terms of other atypical attention patterns, four teachers across the whole range of schools provisions also referred to the phenomenon of “listening but not looking” that they have observed in some children. Teachers described instances of pupils looking away from the teacher or fidgeting during instructional content, leading to the assumption that they were not listening; teachers noted that upon being asked a relevant question or given instructions, these children were able to engage with the material, showing that they had indeed been listening. It is not uncommon for autistic individuals to avoid direct eye contact (Senju & Johnson, 2009), or even demonstrate reduced visual attention to people in general (Riby & Hancock, 2008). This observation from teachers is therefore not unusual, however the phenomenon of being able to process the necessary information without using visual cues has been under-researched. Differences in the observations of this phenomena did exist, however, as one teacher also described other children who look as though they are paying attention (i.e. by looking at the teacher), but in fact have not been listening. These observations reflect the variability seen in divided attention in Chapter Three, where some children were capable of dividing their attention between two sensory domains (i.e. visual and auditory), but other children were not. It is possible that children who are “listening but not looking” have better divided attention ability, in that they are able to look away from the teacher, and can even “fidget with something”, but still attend to and process the auditory information. For children who are looking at the teacher but have not been attending to what the teacher has been saying, this may reflect poor divided attention ability in that they process the visual but not auditory information. This is an issue that will be returned to in Chapter Seven of this thesis, as it is highly relevant in terms of methodological choices in autism research, such as when selecting tasks to measure attention.

A core theme that emerged from the analysis was psychopathology; teachers across all school provisions reported observations that anxiety, sensory issues and restricted interests could be distracting for autistic children while in the classroom. The fact that these issues were prominent across all school provisions suggests that these aspects of psychopathology and their impact on learning are prevalent across the autism spectrum, emphasising the importance of understanding these broad issues.

Anxiety was described as a direct distractor, in that if a child was anxious about something this would maintain their focus and consequently they would be unable to attend to their work. Anxiety is highly prevalent in autism (Weisbrot et al., 2005), therefore it was not surprising that teachers reported it as an issue. Similar relationships between anxiety, attention and academic outcomes have been found elsewhere within the literature; research has found higher levels of anxiety to be associated with poorer academic achievement in both ASD and

TD populations, particularly with maths performance (e.g. Oswald et al., 2016; Owens, Stevenson, Hadwin & Norgate, 2012), as well as links between anxiety and attentional control (e.g. Luxford, Hadwin & Kovshoff, 2017; Reinholdt-Dunne et al., 2015; Richards, Benson, Donnelly & Hadwin, 2014). Eysenck's processing efficiency theory (PET) proposes that anxiety interferes with working memory, which has a subsequent effect upon task performance (Eysenck & Calvo, 1992). The notion is that intrusive thoughts related to anxiety compete for processing resources in working memory, limiting the resources available and necessary to complete the task. The model also assumes that the more difficult the cognitive task the larger the effect. In the context of attention and academic achievement, this suggests that the impact of anxiety upon working memory also influences attentional processes, which leads to poorer academic performance. As anxiety is known to be heightened in ASD (Weisbrot et al., 2005), this has implications for their attention ability and learning, more so than the general population. This was a theme that was also identified in Study 3a, showing the importance of this issue in the perspective of teachers. The current study makes an important contribution towards understanding the interplay between these variables and the real world impact upon daily school life for pupils with autism.

Sensory issues were also reported to have an impact on attention and learning in pupils with autism. Teachers spoke in less detail about this in this section of the interview compared to in Study 3a, although there was a clear theme of sensory processing issues present. Sensory atypicalities are a core feature of ASD (Ben-Sasson et al., 2009; Leekham et al., 2007), therefore its presence in the discourse of teachers was unsurprising. Teachers reported that for some children, the sensory aspects of the environment can become "all encompassing" and almost impossible to ignore. As a consequence, the quality of learning output is poor, or in some cases, entirely non-existent. This supports existing research reporting relationships between sensory processing, attention, and learning in children with ASD (Ashburner et al., 2008); specifically, Ashburner et al. (2008) found that an overall measure of sensory processing, as well as the two sub-scales of under responsiveness / seeks sensation and auditory filtering, were strongly associated with academic achievement and with inattention scores on the Conners' Teacher Rating Scale (Conners, 1990). The exact interplay between attention and sensory processing is unclear; it is possible that sensory issues impact upon a child's ability to attend, but another viable explanation is that children with poorer attention are more likely to experience sensory processing difficulties, which together compound the learning experience. It is, however, also important to recognise the spectrum of sensory processing; children with ASD are known to present with either hyper- or hypo-sensitivity to sensory information (Kern et al., 2006). Sensory hypersensitivity refers to an individual whose sensory experiences are exaggerated or heightened (e.g. being unable to bear clothes rubbing on skin), whereas hyposensitivity reflects reduced sensory stimulation (e.g. not hearing someone calling their name). It is possible that this difference in sensitivity to sensory stimuli reflects differences in the relationship between attention and sensory processing. Considering Ashburner et al.'s (2008) findings that both forms of hyposensitivity (i.e. under responsiveness / sensation seeking) and hypersensitivity (i.e. auditory filtering) were related to attention and achievement, it may be that where a child's sensory processing falls on this spectrum of sensitivity influences attention and learning differently. Equally, a child who is hypersensitive may be distracted by different factors compared to a child who is hyposensitive. Together, the findings from these interviews and experimental work within the literature do indicate the existence of a relationship that warrants a more detailed investigation, particularly considering that these findings are extended across types of school provision (therefore impacting all potential pupils with autism in the education system). As previously mentioned, as this is a broad issue that resonates with teachers from different school provisions, the implications are relevant across the spectrum. Further investigations into these relationships with experimental work could therefore have wide reaching application.

Another core theme identified within the analysis was the classroom environment, which related both to aspects of the classroom that could be distracting for children, as well as strategies that were necessary for supporting the maintenance of a child's attention. Other children and the visual environment were the aspects of the classroom that teachers reported most often as distractors. This links with the experimental findings of Fisher et al. (2014) in their study of visual distraction in the classroom (see Chapter One for a full description). Fisher and colleagues found that in a sparsely decorated classroom, children spent most off-task time engaging in distractions from peers. Comparatively, in the highly decorated condition they spent most off-task time engaging in distraction from the environment, although peer distractions were still present. Both visual and peer distraction could be related to sensory issues; in the current study children were described as being distracted by the noises and activities that other children were getting on with, as well as what was going on outside the classroom windows. This may reflect children who are hypersensitive to the sensory world, whereas children with sensory hyposensitivity may not be impacted by these issues. As was the case with anxiety described above, this could lead to the production of poorer quality work, or no work at all.

In terms of the visual environment being a distraction, this links strongly with the findings of Hanley et al. (2017), where autistic children who spent less time looking at the teacher (and more time looking at the background) during a lesson were found to have poorer learning outcomes. It is, however, important to recognise the finding that teachers reported a discord between visual and auditory attention in autism, in that a child who is listening to the teacher may not be looking at them, and vice versa. This also has implications for the methodological choices made in studies of visual attention, particularly eye-tracking research, including Chapter Four of this thesis, which will be discussed in detail in Chapter Seven. Despite this, Barrett et al., (2015) found that both too much and too little visual complexity in the classroom impacted on academic outcome, therefore it is possible that children who are hypersensitive to visual and auditory stimuli within the classroom are more susceptible to being distracted from their learning task by irrelevant sensory information. Related to this is the concept of increased perceptual capacity in autism, proposed by Remington, Swettenham, Campbell and Coleman (2009), who argue that individuals with autism can process more information at one time compared to TD individuals due to an enhanced perceptual capacity. Using a signal-detection task in which adults with and without autism were required to detect the presence of a visual target in the periphery, Remington, Swettenham and Lavie (2012) showed that autistic individuals maintained high rates of accuracy even in high load conditions. Remington and Fairnie (2017) have also shown that this enhanced perceptual capacity extends to the auditory domain. According to the load theory of attention (Lavie, 2005), if an individual has spare capacity, they will still process task-irrelevant information despite prioritising relevant information, until their capacity is reached. As a result of irrelevant information being processed, the individual is open to distraction from the relevant information (Forster & Lavie, 2007). This may be the mechanism underlying the susceptibility to distraction for children who are hypersensitive to the sensory aspects of the classroom. For these children, having a dedicated staff member to re-direct their attention could be invaluable, as described by teachers. This need for support from additional staff members was only mentioned by mainstream teachers in this section of the interview. It is possible that the lack of teaching assistants in mainstream schools makes it more obvious that this is an important issue compared to SEN schools who have higher teacher to pupil ratio.

This links well to the final theme of engagement that was identified within the data. Engagement was generally described as a facilitator of attention during learning activities, and teachers described strategies, such as prompting, to re-engage children with the learning. Other strategies included adapting the learning task to relate to the child's interests, or building in reward time to the structure of the learning experience to give incentive for children to attend to the task at hand. Although engagement is likely to be an important facilitator of learning for all children, some of the strategies recruited to enable this may be more important for children with autism, for example, incorporating their circumscribed interests into learning tasks to engage attention. Indeed, eye-tracking research has shown that autistic children's visual attention patterns differ from TD children when presented with visual arrays containing both items related to restricted interests (e.g. trains, road signs, computer equipment) and other commonplace items not related to interests (e.g. furniture, clothing) (Sasson et al., 2008; Sasson et al., 2011). Sasson et al. (2008) found that 6 to 17-year-old children with autism made more fixations and perseverated for longer on items related to restricted interests, compared to TD children, whose attention patterns were more balanced. The authors also extended this study to find similar patterns in 2 to 5 year olds (Sasson et al., 2011). This supports the notion that although using circumscribed interests to engage pupils' attention in the learning material is a useful method for all children, the success of this strategy may be more exaggerated in autism due to the preference for information "relevant" to their interests. This is an issue that will be discussed in more detail in the general discussion section of this chapter. Overall, engagement and attention are therefore highly interconnected; attention is necessary for a child to engage with learning, but equally, without engagement strategies, children with autism can struggle to maintain attention on a task.

Bringing together these themes, and the relationships between them, a clear story regarding the relationship between attention, learning and other factors for pupils with autism has begun to emerge. Teacher's perspectives on these issues have reinforced some of the relationships that existing research using different methods originally proposed, but their views have also raised important questions about the overall educational experience for autistic pupils across different types of educational provision. These findings are relevant for theory, practice, and intervention, and highlight the need for further work in these areas.

5.4 General Discussion

This chapter has explored factors that impact upon learning for pupils with autism, including the role of attention, using invaluable insights from teachers who work closely with these children. The first part of this study highlighted a vast and varied range of factors that teachers felt were important for learning, which included i) behaviours and abilities, ii) the practice of teaching, iii) the process and impact of receiving a diagnosis, iv) school and classroom resources, and v) skills and qualities of those teaching pupils with autism. Some of these factors link to the themes explored in the second part of this study, which focused more directly on the role of attention in learning from teacher insights. Recurring themes across both sections included sensory processing difficulties, anxiety, the structure of and engagement in the learning process, how staff support children within the classroom, and the impact these have upon both attention and learning. The analysis of these interviews provided support for existing theories, in addition to highlighting potential avenues for future study.

Of particular significance across both sections of the interview was the relationship between sensory processing, anxiety, attention and learning. Even in the first section, in which teachers were not directly asked about attention, some spoke about sensory processing and/or anxiety in relation to the impact they have upon an autistic pupil's attention, which can lead to poorer learning outcomes, smaller learning output, or no learning at all, including the extreme of exclusion from school. This reinforces the notion that sensory processing issues and anxiety are strongly linked to attention in children with autism (e.g. Ashburner et al., 2008; Luxford et al., 2017), highlighting that this can impact significantly upon their experience in the classroom, and subsequently upon their academic outcomes. Based on the findings from this study, the relationship between attention and learning is likely to be influenced by other factors, particularly sensory processing and anxiety.

The themes that emerged within this study also share some parallel with studies of older autistic individuals, such as those attending higher education (Gurbuz, Hanley & Riby, 2019). In their study of the social and academic experiences of individuals with autism at university, Gurbuz et al. (2019) found that autistic individuals report a wide variety of social and academic factors relevant to their experience within higher education, some of which resonate with the themes that emerged within the current study, namely sensory processing, structure and routine, and the value of support/guidance from educators. Furthermore, in a sample of 2211 incoming postsecondary students with ASD, Sturm and Kasari (2019) recently found that 69% reported feeling depressed and 48% reported having a psychological disorder (compared to 11.9% and 10.7% national norms respectively; CIRP, 2017). This demonstrates that some of the factors that exist in the primary school classroom also continue into early adulthood, emphasising the significance of understanding these issues in childhood, with the aim of achieving better outcomes for autistic individuals.

5.4.1 Relevance of school provision type

Throughout the analysis, it was recognised that particular themes appeared to be more prominent within data from teachers from a particular provision. For example, the theme of "receiving a diagnosis" in Study 3a was only endorsed by mainstream teachers. Equally, however, other themes were present across educational provisions. Recognising which of these themes are unique to school provision type and which transcend provision is an important element of interpreting the findings.

To begin with, the themes that were prominent within only mainstream schools will be discussed. In Study 3a, the themes of "receiving a diagnosis" and "school/classroom resources" were supported dominantly by the data from teachers in mainstream schools. As discussed above, it is likely that these themes were mentioned more often by mainstream teachers due to the lack of funding in this provision type, and subsequently the lack of appropriate SEN resources such as additional teaching staff and equipment. Although these resources may also be important for children in schools with SEN provision, it was not a prominent issue for teachers in these schools, as they do not lack these resources. Related to this theme, in Study 3b, two mainstream teachers described how some children would need dedicated support from a staff member in order to maintain their attention on a task. Again, schools with SEN provision generally have higher staff to pupil ratios, therefore this issue was not prominent one for these teachers. That said, there were opportunities for all teachers to refer to facilitators of learning, therefore it is possible that this issue is truly unique to autistic pupils in mainstream settings.

There were few themes endorsed only by teachers from SEN schools. In Study 3a, it was only SEN teachers who referred to the importance of engaging pupils within the learning experience. This was, however, a theme that also occurred in Study 3b in relation to attention that was endorsed by a range of teachers, therefore it is unlikely to be an issue unique to autism in SEN schools. One sub-theme was clearly prominent in this group, however, mentioned by three SEN teachers; none of the other teachers described the “short attention span” of pupils with autism. Earlier in this chapter, it was speculated that this could be a pattern of attention that characterises autistic children with more complex needs, compared to children with autism in mainstream schools. Another possible explanation could be related to the reduced class sizes in SEN schools; all of the teachers from these schools reported much smaller class sizes compared to teachers from other provisions. One possibility is that these teachers are able to dedicate more of their time to the children in the class with autism, and therefore can recognise subtle aspects of their behaviour and cognition that other teachers may not have the time or capacity to do. This is purely speculative, however, it is important to recognise these differences between teachers and potential differences between the needs of pupils in different types of school provision.

Finally, some of the themes collapsed across educational provision type, suggesting their broad implications for children with ASD in the education system. The most prominent theme in Study 3a, endorsed by all teachers, was “pupil behaviours and abilities”, and within this the sub-theme of “sensory issues”. Similarly, nine out of ten teachers referred to the sub-theme of “anxiety”. These factors and their impact on learning have been discussed in detail above, however it is important to recognise here that these issues are relevant for autistic pupils regardless of the educational provision they are accessing. This is an assumption supported by the literature in terms of the high prevalence rates of both sensory processing (Ben-Sasson et al., 2009; Leekham et al., 2007) and anxiety (Kerns & Kendall, 2012; Weisbrot et al., 2005) in autism. The way in which these aspects of behaviour in autism impact upon attention and learning in the classroom is therefore arguably relationships that should be prioritised for further investigation, due to their broad implications. The sub-theme of "structure, planning and transitions" was also relevant across all school provisions. Considering this was also found to be highly related to anxiety, it is not surprising that this issue was also broadly relevant. Furthermore, rigid adherence to routine is characteristic of autism (APA, 2013), and the use of structure has been suggested as a way to manage this within an educational setting, for example in the "Treatment and Education of Autistic and Communication related handicapped Children" (TEACCH) approach (Mesibov, Shea, & Schopler, 2005). This sub-theme was also prominent within Study 3b, referred to by six out of ten teachers in relation to keeping a child's attention engaged within the learning task.

Recognising the prominence of these issues between different educational provisions highlights their relevance. All of the themes identified within this study are worthy of further investigation, however, the themes that are broadly relevant arguably deserve prioritisation due to their wide-reaching implications for children with ASD.

5.4.2 Specificity of issues to autism

One potential limitation of this study is that although teachers were asked questions specifically about pupils with autism, it is possible that some of the points they raised were not necessarily specific to autism. That said, the aim of the current study was to delve deeper into the factors impacting learning for pupils with autism, not to compare across disorders or with children with different developmental needs. It is however still important to consider whether the factors impacting learning and attention raised by teachers in this study are specific to autism, or are applicable to the education of children more generally. Within the semi-structured interviews, this was a question the interviewer raised, therefore some data is available to directly address this line of enquiry. In the interest of brevity, the themes considered to be most relevant to this issue of autism specificity will be discussed below.

From the interview transcripts, it was clear that some of the factors teachers referred to as having an impact upon learning were not necessarily unique to pupils with autism. One of these sub-themes was communication. Teachers who referred to communication being a gateway for accessing learning in Study 3a also acknowledged that this was indeed an important factor for all children, and was not necessarily specific to autism. This did not, however, make it any less relevant for autistic pupils. This was also a theme mostly endorsed by SEN teachers, mentioned only by one mainstream teacher. It is likely that teachers in SEN schools will come across a wider range of children for whom lack of communication can be a barrier to learning, suggesting this is more general to children with a range of special educational needs, but more autism specific in mainstream settings (i.e. compared to TD children).

The theme of "engagement" in Study 3b was also highlighted in the interviews as not necessarily being uniquely relevant to pupils with autism, and this was acknowledged earlier in this chapter in relation to tailoring learning material to a child's interests. Sasson et al. (2008, 2011) found that autistic children's visual attention patterns were directed more towards restricted interests, compared to TD children whose visual attention patterns were more balanced. This suggests that although the use of these interests in learning material may be beneficial for all children, it has a more exaggerated benefit in autism. Other aspects of engagement mentioned by teachers could be considered in the same way; using structure, for example. This was also discussed in detail in the discussion section for Study 3b, drawing upon the connection between structure and anxiety to conclude that although a highly structured approach to education may be beneficial to all children, this is more exaggerated for children with autism due to the anxiety that uncertainty can cause. Intolerance of uncertainty has also been found to exist in TD populations, although prevalence and severity is significantly elevated in ASD by comparison (e.g. Boulter, Freeston, South & Rodgers, 2014; Neil, Olsson & Pellicano, 2016), therefore the lack of structure may have an amplified negative impact for autistic pupils.

So far, the focus of this section has been upon themes and sub-themes that were not necessarily considered to be specific to pupils with autism. It is also appropriate to recognise themes that were considered by the teachers to be unique to autism. The most prominent of these was the sub-theme of "sensory issues", recognised in both studies. As discussed previously, sensory processing difficulties are a core feature of autism (APA, 2013), and their relationship to both attention and academic achievement are supported by existing literature (e.g. Ashburner et al., 2008). Although variability in sensory processing has been found to exist in the TD population (Little, Dean, Tomchek & Dunn, 2017), teachers recognised that sensory processing was an issue that specifically affected autistic pupils' ability to access learning in the classroom. Some teachers also noted that sensory aspects of the classroom can also be relevant for children with clinically relevant sensory issues, such as sensory processing disorder (SPD), however it could be argued that the relationship between sensory difficulties and learning is compounded in autism due to the contribution of attention atypicalities and RRBs, both of which have found to be related to sensory processing in autism (e.g. Brandes-Aitken et al., 2018; Chen, Rodgers & McConachie, 2009; Wigham et al., 2015). In a direct comparison of selective attention in TD children, children with ASD and children with SPD, Brandes-Aitken et al. (2018) found that selective attention in ASD was poorer than both SPD and TD groups. In the context of the current thesis, if we know that sensory processing is related to both attention and academic achievement in ASD, and that attention is poorer in children with ASD compared to SPD, this supports the notion that the impact of sensory processing issues upon learning is particularly pertinent in autism.

Overall, recognising the specificity of these themes to autism strengthens the interpretation and application of the findings here. Although many of the themes raised within these teacher interviews could be relevant to learning for all children, looking to the wider literature suggests that many of the relationships are exaggerated in autism, highlighting the relative importance of these issues for this group of children in particular.

5.4.3 Limitations

Although these studies have provided valuable insights into teachers' views on the experiences of pupils with autism within the classroom, the qualitative nature of these findings does present some limitations. While the perspectives of teachers were highly informative in terms of highlighting potential issues for autistic children, and how these issues impact upon their learning experience, these are not direct quantitative measurements and there is no certainty that a pupil's personal experience mirrors that observed by their teacher. Indeed, Dekker, Ziermans, Spruijt and Swaab (2017) found weak relationships between teacher rating measures of executive function and cognitive measures of the same constructs. Comparatively, Cabell, Justice, Zucker and Kilday (2009) found that teacher ratings of children's emergent literacy skills were accurate, in that they were strongly correlated with direct assessment of the same skills. It is still important to recognise that although teachers' perspectives are not a direct measurement and may not be able to identify precise cognitive and behavioural mechanisms in the pupils they teach, they do provide a valuable insight that can inform future experimental work.

Another limitation of this study is the small sample size, which is characteristic of semi-structured interviews and qualitative research more generally. Braun and Clarke (2013) recommend that 6-10 is an adequate sample size for semi-structured interviews, maintaining a balance between obtaining enough data to recognise patterns, and the resource cost of collecting, managing and analysing the data. Furthermore, other authors have commented that data saturation (i.e. the point at which no new themes emerge when interviewing additional participants) occurs at around 11 participants (Latham, 2013). Despite this justification of small sample size in qualitative research, it is important to recognise that the small sample of participants means that the findings cannot be generalised. Further to this, the participants recruited were all working in the North East of England, and had a range of teaching backgrounds and experience/knowledge of autism. Including teachers from different school provisions was important for this study, due to the nature of the topic; children with autism attend schools with a range of provisions, therefore accounting for this variability was vital. This added variability, however, further compounds the argument regarding generalizability, which is important to acknowledge when interpreting the data, which has been done in the section above. That said, the patterns identified within this study highlight key issues that can be further investigated using quantitative methods, that may be more successful in producing generalizable findings.

Another important issue to emphasise is the heterogeneity within ASD, which was also highlighted by teachers, and present throughout the empirical chapters of this thesis. For example, in Chapter Three, variability not only in divided attention scores but in ability to complete the task tapping divided attention existed. Furthermore, in Chapter Four, variability was recognised in relation to ability to complete the eye-tracking calibration process. While throughout this thesis, acknowledgement of heterogeneity in autism has been considered a positive perspective to take, it is important to recognise that although the factors and relationships discussed in the current chapter may be relevant for some autistic children, they are by no means generalizable. Indeed, Charman (2015) describes individual differences in developmental research as both a potential avenue for investigation, as well as a hindrance in empirical work. Recognising heterogeneity in ASD research is a vital step towards understanding the experiences of children across the breadth of the autism spectrum, but in order to do so effectively, certain challenges must be overcome. Charman (2015) highlights that most experimental research in autism, and developmental disorders more generally, adopts a between-groups approach to analysing data. Although this method can provide important insights into the differences between ASD and TD children, it ignores the heterogeneity of ASD and its overlap with typical development. Throughout this thesis, there has so far been a focus upon acknowledging this heterogeneity in ASD, therefore it follows to also recognise this within the current chapter. Although the findings from the current study are not entirely generalizable, they do provide valuable real-world insights and can point research in a relevant direction towards understanding the underlying processes at work.

5.4.2 Conclusion

On the whole, this study has highlighted many potential factors with implications for learning in autistic pupils, from the perspectives of those who teach them. Identifying these individual differences, rather than looking at attention and learning in isolation, allows for a holistic approach to understanding the whole child and their experience within the classroom. The findings from these teacher interviews have strengthened and even enhanced the experimental work within this thesis that has so far found relationships between attention and learning to exist in autism, by providing insights from teachers that corroborate with some of the existing findings, and offer new findings to be investigated. The relationship between sensory processing, anxiety, attention and learning was particularly prominent within the teachers' discourse, raising important issues to be investigated further. This chapter highlights that the relationship between attention and learning may not be direct, a finding that is also supported by the empirical work within this thesis. Understanding these potentially complex relationships is vital in order to know how best to support pupils with autism for whom these issues exist, which can be done with the support of empirical research using direct measurements of attention, sensory processing issues, anxiety and achievement; a holistic approach that that will be taken in the following chapter.

Chapter Six: The role of anxiety and sensory processing in the relationship between attention and academic achievement

6.1 Introduction

As previously discussed within this thesis, a variety of factors have been found to predict academic achievement in autistic children (Keen et al., 2016). In Chapter Five teachers' perspectives provided a unique insight into the way in which these factors can impact on learning. In addition to this, this study also demonstrated how some factors interact with both attention and learning. Although a variety of factors were described by teachers in the interviews in Chapter Five, the most compelling and impactful descriptions regarded behaviours relating to psychopathology. Indeed, published studies have also found characteristics associated with autism such as sensory processing atypicalities, social responsiveness and heightened anxiety to be related to attention (e.g. Ashburner et al., 2008; Brandes-Aitken et al, 2018; Liss, Saulnier, Fein & Kinsbourne, 2006), reinforcing the possibility that individual differences in these domains may impact the relationship between attention and academic achievement. The current chapter will investigate this possibility for children with ASD, as well as in TD children for comparison, while recognising the heterogeneity within both populations. As the literature relating to these aspects of psychopathology has not been covered elsewhere in the thesis, the current chapter will begin with an overview of the relevant literature.

6.1.1 Sensory processing

Sensory processing difficulties are known to be prevalent in ASD and are now included in the DSM-5 criteria (APA, 2013). Research suggests that over 90% of autistic individuals experience atypical sensory processing (Ben-Sasson et al., 2009; Leekham et al., 2007), although the pattern of these abnormalities can vary (Kern et al., 2006). As previously mentioned, Ashburner et al. (2008) found that sensory processing severity was related to academic performance (as rated by teachers) in 6- to 10-year olds with autism. Sensory processing was measured using the Short Sensory Profile (SSP; Dunn, 1999), a parent-report measure of their child's sensory experiences. Subscales of the SSP allow observations to be made about specific sensory modalities, such as touch, taste or sound. In Ashburner et al.'s study, overall SSP score, under responsiveness / seeks sensation and auditory filtering were all strongly correlated with academic performance. This was only the case for autistic children, with no significant correlations found within the TD control group. Further to this, in the ASD group only, the same three sensory measures were related to inattention scores on the Conners' Teacher Rating Scale (Conners, 1997). The authors posit that difficulties attending to verbal information in the presence of background noise may be due to finding auditory stimuli "overwhelming or difficult to process" (Ashburner et al., 2008; p. 570), which clearly has implications for focusing on educational tasks within a noisy classroom. More recently, Sanz-Cervera, Pastor-Cerezuela, Fernandez-Andres and Tarraga-Minguez (2015) found that sensory processing was a significant predictor of inattention at home, and that there was a significant relationship between auditory processing and inattention in the classroom, reinforcing the findings of Ashburner and colleagues.

Although both of these studies were positive first steps towards understanding the relationship between sensory processing and attention, they used parent and/or teacher ratings of attention, rather than a direct measure of attention ability. More recent research has, however, investigated these same issues using cognitive assessments of attention. Brandes-Aitken et al. (2018) compared selective attention between children with ASD, children with sensory processing disorder (SPD) and TD children. The comparison between children with ASD and SPD is interesting, since they share some overlap in some but not all features (i.e. sensory processing difficulties vs. RRBs and social communication difficulties). Comparing these groups can offer insights into issues related to sensory processing per se versus complexities that are unique to ASD. The authors used a variety of computerised tasks including flanker, Go/No-Go and visual search tasks, and compared performance between groups. They found that both children with ASD and SPD had poorer selective attention than TD children, suggesting some commonality between these groups in relation to their attention difficulties, subsequently implying that some relationship between sensory processing difficulties and attention may exist. Importantly however, there was also a difference between ASD and SPD groups, in that selective attention was poorer in ASD children. This highlights that although there may be a relationship between sensory processing difficulties and attention, this is compounded by additional features unique to autism.

Few studies have considered the role of sensory processing in attention and achievement for TD children, although in a review of the literature Dunn, Little, Dean, Robertson and Evans (2016) found that auditory and visual processing was related to reading performance for a range of children, including TD and ASD. Indeed, in their study of children at low and high risk of dyslexia, Boets, Wouters, van Wieringen, De Smedt and Ghesquiere (2008) found that visual and auditory processing were related to reading ability in TD children. More recently, Little, Dean, Tomchek and Dunn (2017) classified sensory subtypes of 3- to14-year olds both with and without developmental disorders. They found that TD children were classified within each subtype, showing that higher sensory processing scores were not unique to ASD, and that there was variability within the TD population as well as in ASD. This highlights the importance of considering individual differences in sensory processing scores within a group, as opposed to group mean comparisons that do not take sample variability into account. This is an approach that has been taken throughout this thesis, particularly in relation to the heterogeneity of ASD, and will be returned to in the discussion section of this chapter.

Taking together the existing literature and the findings from Chapter Five, it appears that relationships between academic achievement, attention and sensory processing may exist for autistic children, but this has not yet been investigated using cognitive assessments of attention and achievement within the same study. Furthermore, it is important to consider this relationship for TD children, considering Little et al.'s (2017) finding that sensory processing scores can be highly variable in this population. Understanding the interplay between these factors in a TD population allows for a more meaningful interpretation of the same relationships in autism.

6.1.2 Anxiety

In addition to the core impairments that characterise ASD, research suggests that around half of individuals with autism also experience clinically heightened levels of anxiety (Kerns & Kendall, 2012), with prevalence rates much higher than in TD children (Weisbrot et al., 2005). Furthermore, the existing literature and findings from Chapter Five suggest that relationships between anxiety, attention and academic achievement may exist in both TD and ASD populations (e.g. Oswald et al., 2016; Richards et al., 2014). As described in Chapter Five, Eysenck's processing efficiency theory (PET; Eysenck & Calvo, 1992) may explain this relationship. This theory posits that anxiety incudes thoughts that impact on processing capacity, reducing the efficiency of working memory, and subsequently impacting on task performance. Research has also found that anxiety modulates the functioning of attention in adults (Pacheco-Unguetti, Acosta, Callejas & Lupiáñez, 2010), suggesting that the PET can also be applied to core attentional processes, in addition to higher order cognitive processes. This theory has not specifically been tested in children, however one study did consider the relationship between anxiety, working memory and academic achievement in children, within the framework of the PET. Owens et al. (2012) found that in 10- to 12-year-old TD children, higher levels of anxiety were associated with lower academic performance, and that central executive working memory mediated the relationship between anxiety and academic performance.

To date, no studies have investigated this model in autistic children, although research has independently studied the relationship between anxiety and attentional control (Luxford et al., 2017) and maths ability (Oswald et al., 2016). Luxford et al. (2017) conducted a cognitive behavioural therapy-based intervention with 11- to 14-year-old autistic individuals with high levels of anxiety, investigating its effectiveness upon their anxiety symptoms, social responsiveness, and attentional control. The intervention was delivered in school over six weeks and focused on providing the adolescents with a 'toolbox' of strategies to manage their anxiety. They found that after the six weeks, individuals demonstrated a positive change in their anxiety symptoms, and a marginal improvement in social responsiveness. Although attention control improved compared to the control group at post-intervention and at 6-week follow up, the difference was not time sensitive. If giving autistic adolescents effective anxiety management strategies also improves attentional control, this supports Eysenck's PET (Eysenck & Calvo, 1992), suggesting that the relationship between anxiety and attention may also be relevant for autistic individuals.

In terms of the relationship between anxiety and achievement in autism, Oswald et al. (2016) considered predictors of maths ability in autistic and TD adolescents. Although perceptual reasoning and verbal ability were the strongest predictors of maths ability, test anxiety was also a significant predictor, as was autism diagnosis. In the ASD group alone, however, the relationship between test anxiety and maths ability only approached significance. It is possible that this could be explained by the specificity of the anxiety measure; individuals with autism can experience generalised anxiety, caused by or related to a wide range of factors (e.g. Rodgers, Glod, Connolly, & McConachie, 2012; Wigham, Rodgers, South, McConachie, & Freeston, 2015), therefore the impact of anxiety upon maths ability may not be specific to test anxiety. Related to this, research has found that anxiety may present differently in autism compared to neurotypical populations; for example, Kerns et al. (2014) conducted semi-structured interviews and self-report measures with 7- to 17-year-old individuals with autism and their parents, to examine the phenomenology of their anxiety. They found that 17% of participants presented with traditional anxiety, 15% with atypical anxiety (in that it interacted with ASD characteristics), and 31% with a combined profile. When examining anxiety in autistic children, it is therefore important to acknowledge that anxiety can present differently in this population.

Due to the atypically heightened levels of both sensory processing and anxiety in autism, in addition to the atypicalities and heterogeneity in attention and achievement, the combined effect of these difficulties may be even further exaggerated. Particularly considering that these are all issues that are relevant to the classroom environment, further investigation of the relationships between anxiety, attention and academic achievement is important. To date, these relationships have not been considered within a single study, in either TD or ASD populations.

6.1.3 Current study

The potential role of anxiety and sensory processing in the relationship between attention and learning was a key finding in Chapter Five; teachers' descriptions of the way in which these aspects of behaviour can impact upon attention and subsequently learning for children with autism were striking. Although some empirical evidence of the existence of these relationships exists, to date, no studies have investigated this within a single study using direct measures of attention and achievement. The main aim of this study was therefore to examine relationships between parent ratings[1] of sensory processing and anxiety, a cognitive assessment of attention, and measures of reading and maths achievement, in both TD and ASD children. As autistic children are known to have heightened anxiety and sensory atypicalities (Leekham et al., 2007; Weisbrot et al., 2005), it was predicted that the ASD group would have more severe symptoms of anxiety and sensory processing difficulties compared to TD children. Based on the existing literature, and the findings from Chapter Five, for children with autism, relationships between anxiety, attention and achievement were predicted (Luxford et al., 2017; Oswald et al., 2016), as were relationships between sensory processing, attention and achievement (Ashburner et al., 2008). For TD children, it was predicted that anxiety would be related to attention and academic achievement, based on the findings of previous research (Owens et al., 2012). Due to previous evidence that sensory processing is not related to attention or academic achievement in TD children (Ashburner et al., 2008), no relationships were expected to be present within the TD sample.

A secondary aim of this study was to take within-group variability into account when considering the relationships between behaviour related to psychopathology, attention and academic achievement. While sensory processing issues and anxiety are known to be prevalent in autism, they are variable (e.g. Kern et al., 2006; MacNeil, Lopes & Minnes, 2009), and some research suggests that this is also the case for TD children (e.g. Little et al., 2017). It is therefore important to recognise this heterogeneity within both samples, which is an approach that has been taken throughout this thesis. In light of this within-groups individual differences approach, it was important to include a measure of autism severity, which is known to be related to both anxiety (Kerns et al., 2014) and sensory processing (Hilton, Graver & LaVesser, 2007).

The final aim of this study was to use a measure of anxiety specific to autism, to ensure that the evaluation of anxiety was representative of the presentation atypicalities previously

[1] Parent ratings of behaviour were used because (1) the Spence Children's Anxiety Scale does not have a teacher report suitable for primary school children, and (2) not all children were recruited through schools, therefore access to their teachers was not always possible.

observed in this population (Kerns et al., 2014). The Anxiety Scale for Children with Autism Spectrum Disorders (ASC-ASD; Rodgers et al., 2016) is a relatively new measure, but accommodates the characteristics of anxiety in autism, and has good internal consistency, validity and reliability. Using this measure of anxiety alongside the Spence Children's Anxiety Scale (SCAS; Spence, 1999) allows a more detailed investigation of the relationships between anxiety in autism and the other cognitive and parent-report measures. As the ASC-ASD is intended for parents of autistic children, the SCAS was also necessary so that TD and ASD groups could still be compared on the basis of anxiety.

It is important to recognise that although the aim of this chapter was to provide insight into individual differences in behaviour that may impact upon the relationship between attention and academic achievement in ASD, this study was not originally set up as an individual differences study. Had this been such, hundreds of participants would have been recruited to do so, and this is a limitation that will be returned to in the discussion section of this chapter. Rather, the purpose of this study was to consider these issues within the sample already studied in Chapter Three, with an aim of further investigating the findings from Chapter Five regarding the relevance of anxiety and sensory processing in ASD.

6.2 Method

6.2.1 Participants

The sample consisted of a sub-set of the sample described in Chapter Three. This included 35 TD children (16 males), ranging in age from 6 years and 11 months to 11 years and 1 months (M = 107.23 months, SD = 13.45), and 19 children with ASD (16 males), ranging in age from 6 years and 1 month to 16 years (M = 134 months, SD = 33.82).

6.2.2 Materials

As described in Chapter Three, cognitive ability (WASI-II; Wechsler, 2011), reading and maths achievement (WIAT-II; Wechsler, 2005), and sustained, selective and divided attention (TEA-Ch; Manly et al., 1999) were measured for each child. Full descriptions of these measures are available in Chapter Three. In addition to these standardised measures, four questionnaires were completed by a parent or caregiver of each child, measuring sensory processing, anxiety, and autism severity.

The Short Sensory Profile (SSP; Dunn, 1999) was used to measure each child's sensory processing symptoms. The SSP is a 38-item measure whereby parents rate the frequency with which their child responds to sensory experiences on a 5-point Likert Scale.

The total score ranges from 38-190 with a lower score indicating more impairment. Cut off points are defined for definite difference (38-140) and probable difference (142-154) from typical performances (155-190). The scale comprises seven subscales: tactile sensitivity, taste/smell sensitivity, movement sensitivity, visual/auditory sensitivity, under responsive/seeks sensations, auditory filtering and low energy/weak, each of which also have three classifications for scores as per the above. For under responsive/seeks sensations, scores of 35-27 are typical, 26-24 indicate a probable difference, and 23-7 indicate a definite difference. For auditory filtering, scores of 30-23 are typical, 22-20 indicate a probable difference, and 19-6 indicate a definite difference. Examples of items from the SSP include: ‘withdraws from splashing water’; ‘will only eat certain tastes’; ‘appears to not hear what you say’. The internal consistency of the scale is reported at .95 (Chen et al., 2009), and the current sample had good internal consistency, $\alpha = .9$. The short version of this questionnaire was chosen, over the full scale, due to the amount of time parents were being asked to dedicate to completing questionnaires.

Two parent-report questionnaires were used to measure anxiety symptoms. The first, Spence Children’s Anxiety Scale (SCAS; Spence, 1999), was completed by parents of both TD and ASD children. This 39-item scale is a parental report of children’s anxiety symptoms whereby parents rate the frequency with which their child experiences anxiety on a 4-point Likert Scale (never, sometimes, often, always). The scale provides an overall measure of anxiety, as well as scores for 6 subscales that each tap into a different aspect of child anxiety. The measure uses age (7-13 years old) and gender-based norms to determine whether children fall within a clinically significant or normal range of anxiety, with T-scores of 60 or above indicating clinically elevated levels of anxiety. The six subscales are: panic attack and agoraphobia, separation anxiety, physical injury fears, social phobia, obsessive compulsive, generalised anxiety disorder/over anxious disorder. Examples of items include: ‘my child complains of feeling afraid’; ‘my child is scared of dogs’; ‘when my child has a problem (s)he feels shaky’. In this study, for comparison purposes, raw scores were used. This was due to the fact that five children with ASD fell outside of the range for standardised scores, with one participant younger than 7 and four older than 13. T-scores for these children were calculated based on the standardisation table closest to their age, for the purpose of descriptive statistics, but for correlational analyses and group comparisons, their raw scores were used. Furthermore, analysing raw scores allows for an in-depth examination of variability, which is dampened down with the use of T-scores. The internal consistency of this questionnaire for the current sample was good, $\alpha = .89$.

The second questionnaire used to measure anxiety, the Anxiety Scale for Children with Autism Spectrum Disorders: (ASC-ASD; Rodgers et al., 2016), was only completed by parents of autistic children, as it was developed specifically for children with ASD. The scale has 24 items, and similarly to the SCAS, the frequency of symptoms is rated on a 4-point Likert Scale (never, sometimes, often, always). The scale provides an overall measure of anxiety, as well as scores for 4 subscales: separation anxiety, uncertainty, performance anxiety, and anxious arousal. Examples of items include: 'my child is afraid of new things, new people, or new places'; 'my child worries about being away from me'; 'my child worries that something bad will happen to him/her'. While standardised scores and indicative cut-offs are not currently available for this relatively new measure of anxiety, the authors advise that scores of 20 and above may indicate significant levels of anxiety, and scores above 24 may imply more specific anxieties are present. The internal consistency of this measure for the current sample was acceptable, $\alpha = .72$.

The Social Responsiveness Scale – Second Edition (SRS-2; Constantino & Gruber, 2012) was used as a measure of autism severity. A full description of this measure can be found in Chapter Four. Scaled scores below 59 indicate that the child demonstrates few social difficulties indicative of an ASD diagnosis, scores between 60 and 65 indicate 'mild' social difficulties, scores between 66 and 75 are considered 'moderate' and indicates some clinically significant deficits, and scores above 76 indicate 'severe' clinically significant social deficits. As with the SSP, raw scores were used for correlational analyses due to the issue of reduced variability in T-scores. The internal consistency for the current sample was excellent, $\alpha = .95$.

6.2.3 Procedure

The procedure for children completing standardised assessments is outlined in Chapter Three. For children who were recruited through schools, parents were sent the appropriate questionnaires via the school and asked to complete and return them to the researcher using a prepaid envelope. For children whom the researcher visited at home, parents were given the questionnaires in person and mostly completed them while the researcher was working with their child. Each questionnaire took approximately 5-10 minutes to complete.

6.3 Results

6.3.1 Typically developing children

In relation to cognitive profile, the group of TD children described here are representative of the full TD sample described in Chapter Three, as can be seen from their performance across the cognitive, attention and achievement measures (Table 6.1). In terms of their behavioural profile, the group had mean scores that are typical of a TD population, and Figure 6.1 shows the distribution of scores for each measure. The average SRS score of the group was typical, although scaled scores ranged from 40 to 77, with the scores of 2 children falling within the 'mild' range, 5 within the 'moderate' range, and one within the 'severe' range (Figure 6.2).

The sensory processing experiences of TD children was also wide ranging, with raw scores of 100 to 190, which included five children whose scores fell into the 'definite difference' classification, two within the 'probable difference' classification (Figure 6.3). Despite this, most children (N = 28 out of 35) were classified as having typical sensory processing experiences, and the mean group score was within the typical range. For the under responsive/seeks sensation subscale, the group average was in the typical range, with only six children having scores outside of this range. The group average for the auditory filtering subscale was also typical, with the scores of three children classified as 'probable difference' and five classified as 'definite difference'.

In relation to anxiety (using the SCAS-P), the group mean was typical as indicated by the standardised scores. Anxiety symptoms ranged from 40-65, with five children scoring within the clinical range for elevated levels of anxiety (Figure 6.4).

Correlations between each of the measures for the TD sample are presented in Table 6.2. Raw scores for the SRS and SCAS were used to mitigate any floor or ceiling effects in the standardised scores. In interpreting correlations, it is important to reflect that a high score on the SSP indicates more typical sensory processing, which is the opposite to other measures used. Therefore, for example, negative correlations between sensory processing and achievement would indicate that children with typical sensory processing achieved higher academic outcomes. As observed in the sample described in Chapter Three, IQ was strongly correlated with reading and maths achievement, but not with any of the attention measures. In terms of relationships between attention and achievement, similar to the previous chapter, selective and divided attention were not correlated with either achievement measure for TD children. Contrastingly, however, the relationship between sustained attention and reading achievement was not significant in this smaller sub-sample.

Table 6.1. Means and standard deviations for TD and ASD sample measures

	TD (N = 35) M (SD)	ASD (N = 19) M (SD)	Group differences (t)
Age in months	107.23 (13.45	134 (33.82)	-4.14***
FSIQ	102 (11.6)	90.84 (15.44)	2.99**
Reading achievement	106.51 (11.44)	89.84 (21.4)	3.74***
Maths achievement	107.09 (17.15)	83.32 (26.69)	3.98***
Selective attention	6.83 (2.61)	5.63 (3.22)	1.48
Sustained attention	8.86 (2.99)	8.37 (3.56)	.54
Divided attention	7.89 (3.43)	4.05 (4.42)	3.54***
SRS Scaled	51.03 (11.6)	74.84 (10.05)	-7.54***
SSP	169.63 (22.84)	125.68 (28.49)	6.18***
Under responsiveness	30.49 (5.62)	23.68 (7.84)	3.69***
Auditory filtering	21.14 (5.41)	17 (5.13)	5.38***
SCAS Scaled	49.02 (8.27)	60.84 (7.78)	-5.11***
ASC-ASD	N/A	21.58 (12.12)	N/A

** p <.01, *** p < .001

In terms of the relationship between achievement and the behaviour data, reading achievement was significantly positively correlated with social responsiveness, and negatively correlated with sensory processing experiences, but not with anxiety symptoms. This suggests that children with more severe symptoms of social functioning and sensory processing difficulties had poorer reading achievement scores, but that symptoms of anxiety were not related to reading performance. Maths achievement was not related to any of these measures. In relation to the subscales of the SSP, reading was positively correlated with both under responsiveness and auditory filtering, but maths was not.

Selective and sustained attention were not related to any of the behaviour measures however divided attention was correlated with social responsiveness, overall sensory processing, and auditory filtering, but not with under responsiveness or anxiety. This suggests that children with poorer divided attention had more severe social difficulties and more

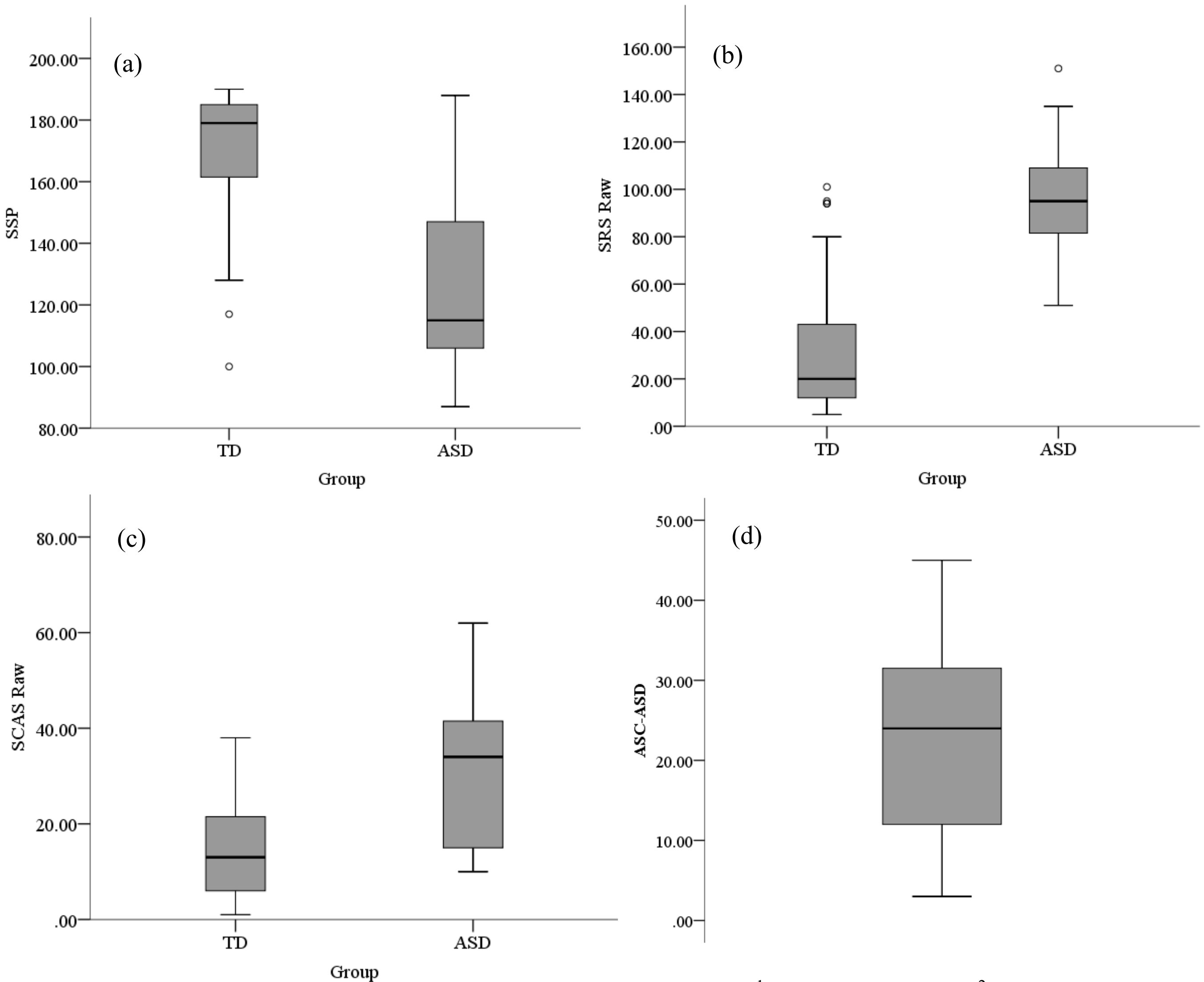


Figure 6.1. Box plots for TD and ASD samples for (a) SSP scores[1], (b) SRS raw scores[2], (c) SCAS raw scores[2], (d) ASC-ASD scores[2].

[1] Higher scores reflect more typical functioning, [2] Higher scores indicate less typical functioning

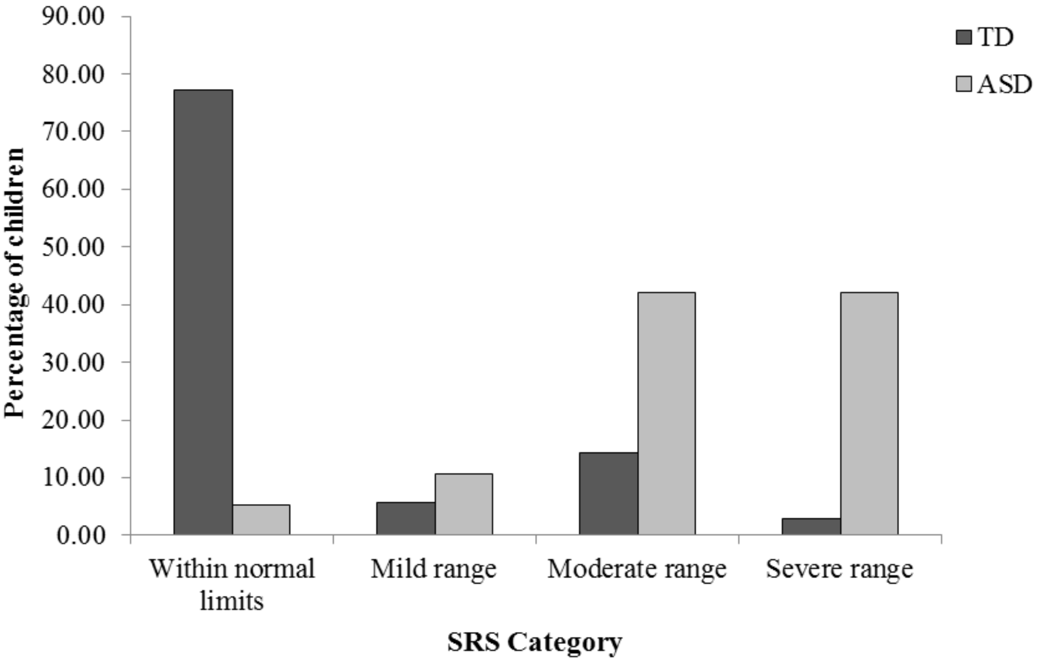


Figure 6.2. Percentage of TD and ASD children who scored within each category of the SRS

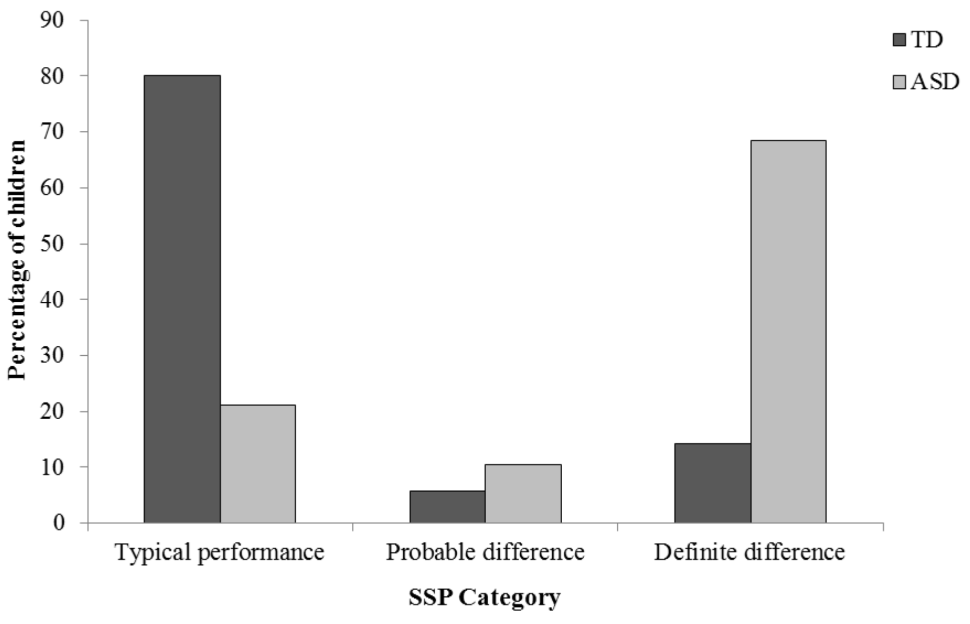


Figure 6.3. Percentage of TD and ASD children who scored within each category of the SSP

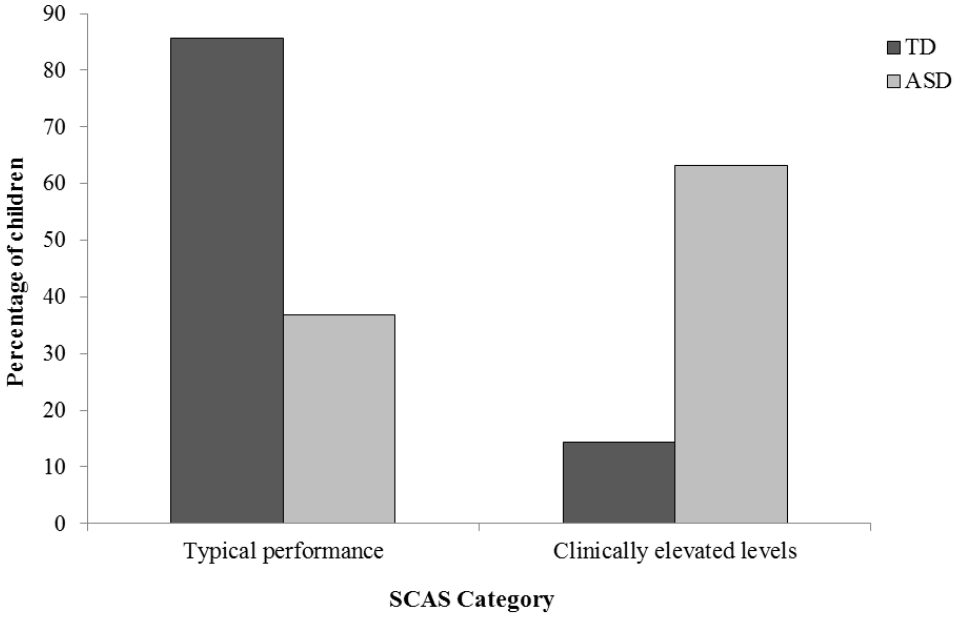


Figure 6.4. Percentage of TD and ASD children who scored within each category of the SCAS-P

symptoms of sensory processing issues. More specifically, children with poorer divided attention had poorer auditory filtering.

Finally, all of the behaviour measures were correlated with one another. Children with more symptoms of social functioning difficulties also had more sensory processing difficulties and anxiety symptoms. Equally, children with more severe sensory processing difficulties also had higher levels of anxiety.

6.3.2 Autistic children

The cognitive profile of this sample is representative of the full sample described in Chapter Three, in relation to performance across attention, cognitive ability and achievement measures (see Table 6.3). The behavioural profile of the group was highly variable (Figure 6.1), as expected from an ASD sample, but group averages suggested that symptoms of each behaviour were more severe than TD children (Table 6.1). The group average SRS score fell within the moderate social difficulties range, with a total of eight children scoring within this range, eight scoring within the 'severe' range, two within the 'mild' range, and one child who scored 2 points below the cut-off for 'mild' social difficulties (Figure 6.2).

Sensory processing experiences also varied widely, with scores ranging from 87-188, an even larger range than for the TD children. The group average for sensory processing was within the 'definite difference' classification with over half of the sample's scores falling within this range (N = 13). Two of the children's scores were classified as a 'probable

Table 6.2. Correlation matrix for TD sample (N = 35)

	Reading	Maths	SCAS (raw)	Auditory filtering	Under responsiveness	SSP	SRS (raw)
IQ	.451**	.546***	.076	-.357*	-.187	-.213	.173
Selective attention	-.149	.189	.049	.018	-.012	.025	-.087
Sustained attention	.181	-.087	-.054	.067	.141	.094	-.155
Divided attention	.062	.158	.223	-.415*	-.102	-.35*	.378*
SRS (raw)	.339*	-.265	.526***	-.739***	-.767***	-.856***	
SSP	-.426*	-.291	-.457**				
Under responsiveness	-.431**	-.222	-.367*				
Auditory filtering	-.338*	-.41*	-.401*				
SCAS (raw)	.087	-.173					

*p <.05, ** p <.01, *** p < .001

Table 6.3. Correlation matrix for ASD sample (N = 19)

	Reading	Maths	ASC-ASD	SCAS (raw)	Auditory filtering	Under responsiveness	SSP	SRS (raw)
IQ	.813***	.806***	.349	.31	.044	-.085	-.149	-.159
Selective attention	.247	.307	.521*	.431	-.444	-.073	-.359	.257
Sustained attention	.227	.291	.337	.223	.015	.412	-.029	.212
Divided attention	.646**	.766***	.488*	.539*	-.289	-.19	-.388	.142
SRS (raw)	-.01	-.022	.679***	.627**	-.575**	-.154	-.634**	
SSP	-.371	-.196	-.641**	-.689***				
Under responsiveness	-.175	-.139	-.035	-.131				
Auditory filtering	-.173	.011	-.528*	-.603**				
SCAS (raw)	.528*	.358	.924***					
ASC-ASD	.446	.3						

*p <.05, ** p <.01, *** p < .001

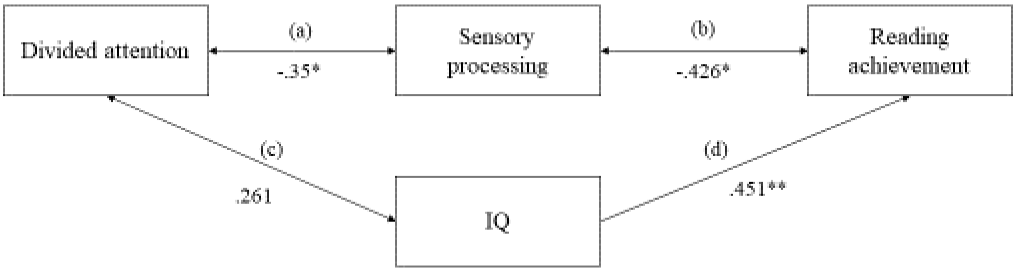
difference' in sensory processing, and the remaining four children had typical performance (Figure 6.3). The under responsive/seeks sensation subscale group average was on the border of 'probable' and 'definite' difference, with almost half of the children (N = 9) classified as having a 'definite difference' in this subscale, two within the 'probable difference' range, and the remaining eight had typical performance. For auditory filtering, the group average indicated 'probable difference', although most scores (N = 14) fell within the 'definite difference' range, four performed typically, and one score was classified as a 'probable difference'.

As with the other behavioural measures, anxiety scores were highly variable, with SCAS T-scores ranging from 45 to 70. The group mean fell just above the cut-off for clinically significant elevated anxiety symptoms, and the majority of children (N = 12) scored within this range (Figure 6.4). Scores on the ASC-ASD were also wide ranging (3-45), and the group average was just above the cut-off for an indication of significant levels of anxiety. This is a relatively new measure of anxiety, and was strongly correlated with SCAS scores, suggesting strong validity as a measure of anxiety ($r = .924$, $p < .001$).

The correlations between measures for the ASD group are presented in Table 6.3. As in the larger sample described in Chapter Three, IQ was significantly related to both reading and maths achievement, as well as divided but not sustained or selective attention. Divided attention was also the only attention measure significantly related to reading and maths achievement. Reading achievement was strongly and positively correlated with anxiety symptoms as measured by the SCAS, and the correlation with ASC-ASD approached significance, but reading was not related to any of the other behaviour measures. No significant relationships between maths achievement and the behaviour measures were found. There was a positive relationship between divided attention and anxiety symptoms, both in terms of SCAS and ASC-ASD scores, in that children with more reported anxiety symptoms had poorer divided attention, but divided attention was not significantly related to any of the other behaviour measures. Selective attention was related to ASC-ASD scores, and approached significance with SCAS, $r(19) = .431$, $p = .066$, but sustained attention was not related to any of the behaviour measures.

As with the TD children, all behaviour measures were correlated with one another. Children with more severe autism symptoms also had higher levels of anxiety and more severe sensory processing difficulties. More specifically, anxiety was related to auditory filtering but not under responsiveness. This suggests that while children with general sensory processing difficulties are likely to have higher levels of anxiety, this may be more specific to the filtering of auditory stimuli.

TD children



ASD children

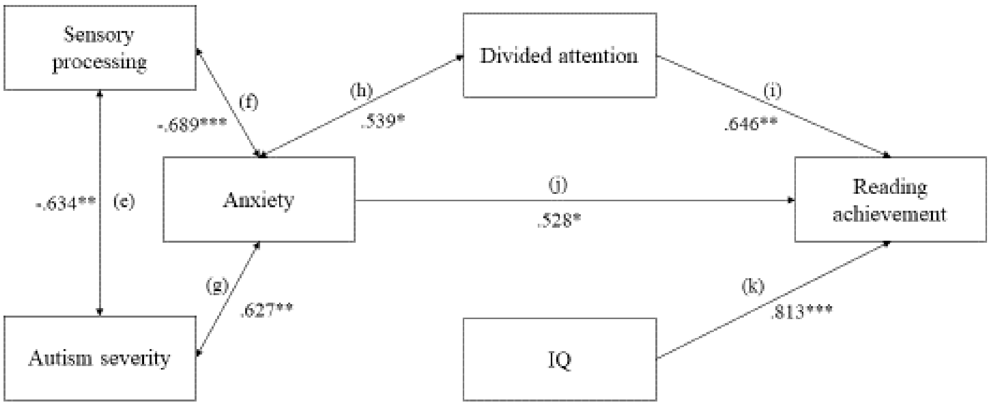


Figure 6.5. Visualisation of proposed relationships between behaviour, attention and reading achievement in TD sample (top) and ASD sample (bottom) *p <.05, ** p <.01, *** p < .001

6.3.3 Modelling relationships

Figure 6.5 depicts the relationships within the TD and ASD groups, based on the correlational data. Ideally, these would be modelled using structural equation modelling (SEM) or path analysis, however this requires a sample size at least 10 times the number of parameters (Kline, 1998). Therefore this was not possible with the existing data set. Presented here are proposed models that could be tested using statistical analysis in future research with appropriate sample sizes. The model is based on correlational data, therefore no causal relationships could be inferred. Despite this, some predictions for certain relationships could be made based on established findings within the existing literature and the findings from Chapter Five of this thesis.

At the core of the TD model is the indirect relationship between divided attention and reading achievement via sensory processing. The model proposes that children with better divided attention have fewer sensory processing difficulties (see (a), Figure 6.5), and that children with fewer sensory processing difficulties have better reading achievement outcomes (see (b), Figure 6.5). Furthermore, the model proposes a similar indirect relationship between divided attention, IQ and reading achievement, in that children with lower IQ scores also have poorer divided attention (see (c), Figure 6.5) and poorer reading achievement scores (see (d), Figure 6.5).

The model for ASD children is more complex. Importantly, divided attention is directly related to reading achievement (see (i), Figure 6.5), but is also related to anxiety (see (h), Figure 6.5). Furthermore, anxiety is directly related to reading achievement (see (j), Figure 6.5). In the proposed model, therefore, children with higher levels of anxiety also have poorer divided attention, which impacts upon their reading achievement. That said, it is also important to recognise that children with heightened anxiety levels may also have poor reading achievement regardless of their divided attention ability. This is represented in the model by both direct (j) and indirect (h, i) relationships between anxiety and reading achievement. Also included in the model is IQ, which influences reading achievement (see (k), Figure 6.5). Finally, the model includes sensory processing and autism severity, as both of these aspects of behaviour are related to levels of anxiety (see (g) and (f), Figure 6.5).

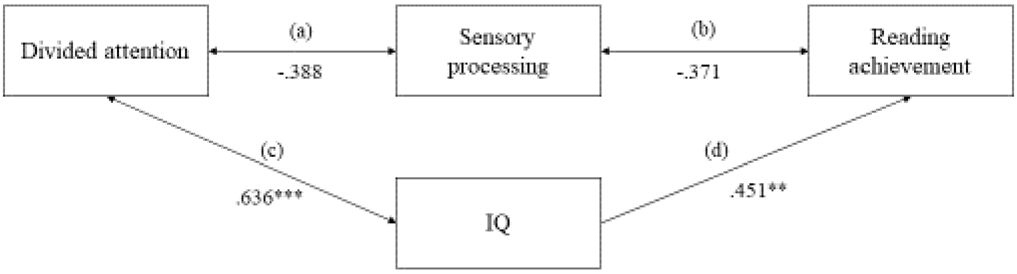
To demonstrate that these models are uniquely appropriate, Figure 6.6 presents the same models with the correlation values but for the alternative group. In other words, the top model is the original TD model, plotted with data from the ASD group. As can be seen from these values, the only aspect of the model supported in this group is the relationship between divided attention and IQ (see (c), Figure 6.6) and between IQ and reading achievement (see (d), Figure 6.6). The bottom model shows the original ASD model, with correlations from the TD group. The only aspect of this model supported by the TD data is the relationship between IQ and reading achievement (see (k), Figure 6.6) and the relationships between sensory processing, autism severity and anxiety (see (e), (f) and (g), Figure 6.6). This may be due to the issue of shared method variance, which is discussed in detail below.

6.4 Discussion

6.4.1 Typically developing children

For TD children, anxiety symptoms were generally within the typical range, although there was some heterogeneity in the sample as five children had scores that indicated clinically heightened levels of anxiety. It is not unusual for primary school aged TD children to experience anxiety, with general population prevalence rates varying from around 3% to 24% (Cartwright-Hatton, McNicol, & Doubleday, 2006), therefore this distribution is

TD model plotted with ASD data



ASD model plotted with TD data

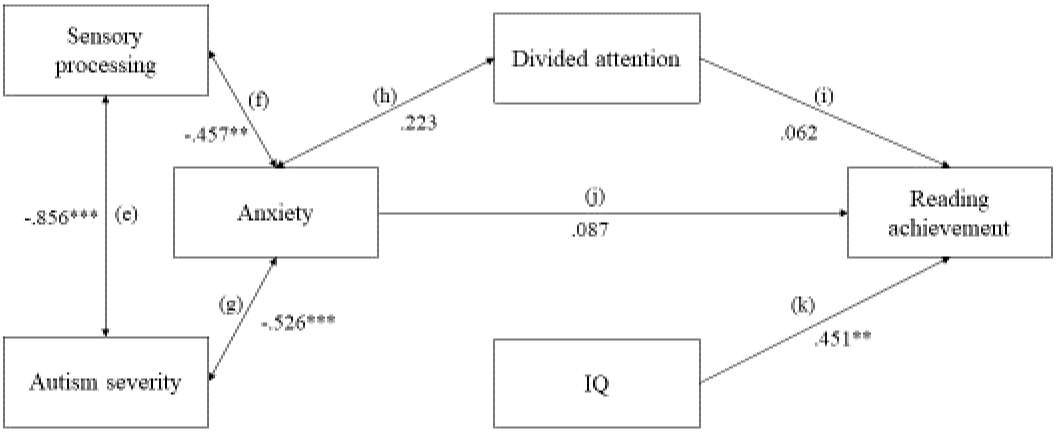


Figure 6.6. Models plotted with alternative group data, including TD model plotted with ASD data (top) and ASD model plotted with TD data (bottom) *p <.05, ** p <.01, *** p < .001

representative of the existing literature. Anxiety did not appear to be directly relevant for attention or achievement in this sample, with no significant correlations between these measures. This was surprising, as previous research has found higher levels of anxiety to be related to poorer academic outcomes (Owens et al., 2012). That said, there were two key differences between measures of achievement and anxiety in the current and previous studies. First, Owens et al. (2012) used a composite score of academic performance, based on National Curriculum Standard Assessment Test (SAT) results for English, Maths and Science. It is possible that the relationship between anxiety and achievement is domain general for TD children, therefore when observing correlations between anxiety and domain specific measures of achievement (i.e. reading and maths), these relationships do not emerge. Second, Owens et al. (2012) used a self-report measure of anxiety, and there are known limitations to doing so with a young sample, including the effect of social desirability (Silverman & Ollendick, 2005), and poor understanding of questions (Breton et al., 1995). It is therefore possible that the use of parent-report rather than child-report measure of anxiety led to this discrepancy. Due to the findings here, anxiety was not included in the TD model (Figure 6.5). As described above, it is possible that anxiety is related to domain-general achievement in TD children, therefore future studies examining similar relationships for domain-general achievement should still consider anxiety as a possible influencing factor.

The ratings of autistic symptoms for most children were within the typical range, with scores from eight children falling outside of this; only one of these children scored in the 'severe' range. This within-sample variability is reflective of previous findings (e.g. Constantino & Todd, 2003), but the fact that TD children who scored outside the typical range were included in the sample is a potential limitation of the current study that will be discussed in more detail below. The finding that autism symptoms in TD children was related to attention and reading achievement is novel, although autism severity has been linked to reading ability in children with autism (Miller et al., 2017); the variability of SRS scores in the current sample may have enabled the emergence of this relationship within a sample of TD children. It is important to note, however, that SSP and SRS scores were significantly correlated with one another, therefore it is likely that they share some variance. With this in mind, one possible explanation is that children with more autistic symptoms were also likely to present with sensory processing difficulties, which impacted on attention and reading achievement. The relationships between these measures may, however, be a result of shared method variance, and this is an issue that is discussed in more detail below. Due to this uncertainty, autism severity was not included in the TD model, however larger studies of individual differences in academic achievement should consider autism severity as a potentially relevant factor.

Sensory processing scores fell within the typical range for most children, although seven children scored outside of this range, showing that the sensory experiences of TD children were heterogeneous. This is consistent with previous literature (Little et al., 2017). In terms of relationships with other measures, children with more pronounced symptoms of sensory processing difficulties had poorer divided attention and reading achievement, and this formed the basis of the TD model (Figure 6.5). The literature regarding the relationship between sensory processing and achievement in TD children is mixed, although these findings do concur with studies that found relationships between visual and auditory processing and reading ability (Boets et al., 2008; Dunn et al., 2016). Conversely, these findings contradict those of Ashburner et al. (2008), who found no relationship between sensory processing and attention or achievement for TD children. Their study did, however, use teacher-report measures of attention and achievement. By comparison, the current study measured attention and achievement using standardised assessments and therefore reflect the cognitive processes as opposed to teacher observations. Furthermore, Ashburner et al. controlled for autism related difficulties in their TD group, suggesting a less varied sample compared to the TD sample in the current study. As the current study found relationships between autism symptoms and sensory processing, it could be that the reduced variability of Ashburner et al.'s TD sample meant any relationship between sensory processing and attention or achievement was not detected. The relationships here are interesting, as although sensory processing was related to both divided attention and reading achievement, attention and achievement were not related to one another. This suggests that sensory processing impacts upon a TD child's ability to divide attention between visual and auditory stimuli, but that this does not impact directly upon learning. Indeed, auditory filtering but not under responsiveness was related to divided attention, suggesting that auditory sensitivity was related to performance on this task. This reinforces the notion that attention-sensory and sensory-achievement relationships were independent of one another.

6.4.2 Autistic children

Relationships between cognitive measures reflected the same patterns observed within the larger sample in Chapter Three, in that reading and maths achievement were both related to IQ and divided attention, but not to sustained or selective attention. Autism severity and sensory processing were not directly related to any of the cognitive measures, which was surprising considering previous research has found relationships between sensory processing, attention and academic achievement (e.g. Ashburner et al., 2008; Sanz-Cevera et al., 2015). As previously discussed in relation to TD children, however, previous studies have used teacher or parent report measures of attention and achievement, which could explain the disparity between these studies and the findings here. That said, it was surprising that no relationship between sensory processing and attention existed here, considering the findings from Chapter Five in which teachers described the impact of sensory processing difficulties upon attention for children with autism in the classroom. This inconsistency could be related to the difference in observers; in Chapter Five, teachers reported observations of children in the classroom, while the current study includes sensory ratings from parents. Some studies have found that parent reports of their child's sensory processing in the familial environment may not reflect the child's sensory experience in the classroom (e.g. Brown & Dunn, 2010; Fernandez-Andres, Pastor-Cerezuela, Sanz-Cevera, & Tarraga-Minguez, 2015). Indeed, Fernandez-Andres et al. (2015) found significant differences in sensory processing scores when comparing reports from teachers and parents; teachers reported greater issues with touch and praxis (i.e. motor planning) than parents. Interestingly, these differences only existed for individuals with autism; the TD comparison group scores did not differ based on informant.

This suggests that while the sensory experiences of TD children may comparable between home and the classroom, they may differ for individuals with ASD. This suggestion warrants further investigation. Furthermore, research has found that different sub-profiles of sensory processing exist within ASD, and that these subgroups are differentially associated with a variety of cognitive and behavioural patterns (e.g. Lane, Molloy & Bishop, 2014). It is therefore possible that relationships between sensory processing, attention and achievement only exist for a sensory subgroup of children with ASD. Again this suggestion warrants future investigation.

Anxiety was important for this sample; both measures of anxiety were significantly related to divided attention and reading but not maths achievement. This supports the finding in Chapter Five that anxiety can impact upon a child's ability to attend to learning related tasks, which subsequently leads to an impact on learning in terms of quality or quantity of academic output. Building upon this further, the findings here suggest that anxiety can impact on attention and subsequently upon domain specific learning (i.e. reading achievement), which is an entirely novel finding. In this sample, maths achievement did not appear to be impacted by anxiety, which was also found to be the case by Oswald et al. (2016). The domain specificity of this anxiety-attention-learning relationship may be understood further by looking back at the findings in Chapter Three, in which autistic children with poorer divided attention had discrepancies between their word reading and reading comprehension. It is possible that the reduction in attentional capacity, caused by anxiety, may not restrict their basic word reading ability, but rather prevent them from applying their understanding of words to the context of the wider text passage. Overall, relationships that emerged within this sample support the PET model of anxiety (Eysenck & Calvo, 1992); heightened levels of anxiety impacted on processing capacity leading to reduced capacity for cognitive processes, such as attention, which are necessary for engaging with learning activities. As a result of reduced attention to a reading related learning task overall reading outcomes were poorer due to reduced time spent attending during lessons. In the context of the executive dysfunction theory of autism it is also possible that children with poorer divided attention abilities are more susceptible to this effect; if a child already has atypical executive function this may further compound the effect that anxiety has upon processing capacity and subsequently upon the ability to attend to and engage with a task.

As with the TD sample, however, it is important to recognise that all of the measures of behaviour were related to one another, suggesting some shared variance that could be related to autistic traits. Higher levels of anxiety were associated with more severe symptoms of autism, which has also been found previously (Kerns et al., 2014). Additionally, children with more sensory processing difficulties had more severe symptoms of autism and higher levels of anxiety. This relates to comments made by teachers in Chapter Five, who described relationships between sensory processing and anxiety; the presence or anticipation of sensory stimuli (e.g. noise) can provoke anxiety in children with autism, which becomes such a distraction that they are unable to focus on their work. Only anxiety was directly correlated with divided attention and reading achievement, therefore autism severity and sensory processing difficulties may lead to heightened anxiety. Indeed, South and Rodgers (2017) proposed a model of anxiety in autism that includes contributions from sensory and cognitive factors, which suggests that uncertainty about how to deal with sensory sensitivities leads to heightened anxiety. In the present sample sensory processing and autism symptoms do not appear to be directly related to attention or achievement, but an indirect relationship via anxiety may exist. Related to the concept of intolerance of uncertainty, discussed in Chapter Five and at the core of South and Rodgers' (2017) model, it may be that the unpredictability of the primary school classroom is overwhelming for individuals with ASD. Indeed, this could have a chain of impact on sensory processing experiences, anxiety, and subsequently upon attention and learning. For example, hearing is the most affected sensory modality in the classroom for children with ASD (Fernandez-Andres et al., 2015) and unpredictable noise is common in classrooms. As teachers described in Chapter Five, this can include noise from other children, from outside the classroom, or other noises in the school such as fire alarms. If children with ASD are particularly sensitive to noise, this may lead to heightened levels of anxiety, both in immediate reaction to the noise and in anticipation of the noise. As described above, increased anxiety then leads to reduced attentional capacity, which means children cannot focus on the learning task and subsequently achieve less academically. If this process continues over time, this significantly reduces the time spent learning in the classroom, leading to poorer academic outcomes long-term. This implies that although attention is the core cognitive process that is necessary for learning, autistic children may not be able to access attention due to underlying issues related to psychopathology. As a consequence, it may be a priority to address these issues before any attempt to improve attention ability can be made.

6.4.3 Limitations

Measures of behaviour in this study were taken using parent-report measures of anxiety, autism symptoms and sensory processing experiences, which as previously discussed may not be entirely reflective of the experiences of children while they are in the classroom (e.g. Fernandez-Andres et al., 2015). This was discussed in relation to the ASD sample, in that this may explain the disparity between findings in Chapter Five and the current chapter, however it may also be relevant for the TD sample. Previous research in TD children has found relationships between anxiety and achievement (e.g. Owens et al., 2012), which were not present in the current study. It is possible that this was due to the use of parent-report measures of anxiety over self- or teacher-report measures, which would be more relevant for assessing whether anxiety impacts upon attention and learning in the classroom environment. Some caution must therefore be exercised when interpreting the findings of the current study, and future research in this area should consider collecting data from teachers as well as parents.

Another limitation of this study related to using parent-report measures is the issue of shared method variance. Each of the behaviour measures were correlated with one another. One explanation for this is that they are overlapping concepts that share some variance, but another is that the questionnaires were all completed by a single informant whose responses between the questionnaires were related. For example, a parent reporting high on one measure may be more likely to report high on another measure. This is a concept that is known to exist with self-report measures (for a review see Podsakoff, MacKenzie, Lee & Podsakoff, 2003), but is also relevant to parent-report measures as at the core of this concept is the fact that the measures originate from the same respondent. Podsakoff et al. (2003) highlight various reasons for shared method variance to occur with common respondents, which can include the desire to complete questionnaires in a particular way, attempts to maintain consistency between reports, and affectivity or mood states at the time of completion. As a result, this can inflate the observed correlations between measures. One way to control this issue is to obtain reports from different sources, for example in this case, from a teacher, parent and self-report. As described above, discrepancies between these reports can exist due to the context in which the participant is seen, however obtaining these multiple informant reports could be one way to combat the issue of shared method variance.

When interpreting the findings of this study it is also important to recognise that some children within the TD group scored outside of the typical range on each of the parent-report measures. These children were included to provide a group with a varied distribution, and this was considered a reasonable approach, particularly since the group averages were still within the typical range. That said including these children could be construed as a limitation, particularly in relation to SRS scores; considering that this was a study of children with and without ASD, children in the TD group with high SRS scores would typically be excluded from the analysis. The purpose of this study was not, however, to directly compare groups; rather the aim was to consider individual differences within groups. Including these children in order to appropriately answer the research questions was therefore considered to be more important in this particular study. Despite this, acknowledging this potential limitation when interpreting the findings is necessary. Including TD children with high SRS scores may have impacted on the relationships presented within the model. For example, sensory processing and SRS scores were correlated with one another, and although this has already been discussed above in relation to shared method variance, it is possible that these are overlapping concepts that share variance. It is therefore possible that in the TD model, the relationship between sensory processing and reading achievement may have in some way been impacted by the high autism symptoms in some TD children. Future research with much larger samples should be conducted to investigate this further.

A final limitation of this study is that the sample size was too small to conduct any analyses that would allow predictive model testing, therefore assumptions about causal relationships described are speculative. That said, some of these relationships were also described in Chapter Five by teachers, which strengthens the proposed models described in the current chapter. As mentioned in the introduction, this is also a very small sample for a typical individual differences study, which would have hundreds of participants. The purpose of the current study, however, was to use the same sample from Chapter Three to investigate the issues raised by teachers in Chapter Five; the current study never intended to make broad claims about individual differences and the relationship between attention and achievement. These studies have however made an important first step towards understanding the relationships at play, in that the findings have allowed speculative models to be proposed. Future research should build upon this further by testing the proposed models using larger samples.

6.4.4 Conclusions

Overall, individual differences in behaviour were related to divided attention and reading achievement for both TD and ASD children, albeit in different ways. For TD children, sensory processing was important for reading achievement and divided attention, but that these relationships were independent of one another. For children with autism, anxiety, divided attention and reading achievement were all related, suggesting that both anxiety and attention play an important role for children while learning in the classroom. This finding corroborates with teachers' experiences in Chapter Five, who described their observations of anxiety impacting on an autistic child's ability to attend in the classroom, resulting in them producing less or lower quality work. These findings also relate to Eysenck's processing efficiency theory, suggesting that this theory of anxiety impacting on processing capacity may also be relevant for children with autism. Vitally, the findings here indicate the importance of individual differences in behaviour upon the role of attention in learning for autistic pupils. Although sensory processing and autism symptoms did not directly relate to attention or achievement, they were both strongly related to anxiety, therefore they still play an important role in the classroom experience and should be taken into account. While throughout this thesis it has been clear that attention is an important ability to target in terms of educational intervention, it may be the case that children with severe anxiety must first be supported in managing their anxiety as a first step towards improving attention, and subsequently learning outcomes.

Chapter Seven: General Discussion

This thesis aimed to explore the role of attention in learning for pupils with and without autism using a mixed methods approach. The purpose of incorporating multiple methodologies was to gain a rich and broad understanding of attention in autism and how it might impact on learning for autistic pupils. The main findings from this detailed investigation are discussed below, including a discussion of the associated implications. Finally, the strengths and limitations of this thesis will be discussed, as well as suggestions for the direction of future research.

7.1 Summary and implications of findings

7.1.1 Attention in autism

In Chapters Three and Four, data on the attention abilities of children with and without autism was collected using a range of different methods. This included standardised measures of sustained, selective and executive attention using the TEA-Ch, computer-based measures of the same three attentional components using the ANT, and a direct measure of visual attention during a task using eye-tracking. This comprehensive assessment allowed for a detailed examination of the attentional profile in autism, as well as a comparison against TD children. Using a range of methods enabled factors such as verbal instruction and task difficulty to be accounted for. In Chapter Three, it was found that while sustained attention was typical in autistic children, selective and executive attention performance was poorer for children with autism compared to TD children. These findings are consistent with the existing literature (e.g. Keehn et al., 2010; Mutreja et al., 2015), however many autistic children struggled to even complete the divided attention task, raising concerns regarding the suitability of the task. It was proposed that i) the verbal comprehension needed to understand the task was limiting performance, and/or ii) the task tapped a particular type of executive attention that was especially difficult for these children. As a result, an aim of the studies in Chapter Four was to use tasks that could combat these measurement issues. The ANT was considered suitable for this purpose, as it required minimal verbal instruction and all three attention components were examined within the same task. This meant that task demands were similar across conditions measuring these three attention components, therefore any differences between attention measures could not be attributed to understanding of instruction. The findings from the analysis were less clear, in that the attentional profiles of TD and ASD children did not differ. That said, autistic children did not benefit from auditory alerting cues or visual orienting cues; the presence of alerting and orienting cues did not improve accuracy, which is indicative of atypicalities in sustained and selective attention respectively. This inefficiency of sustained attention supports existing literature using the ANT (Samyn et al., 2017) but does not concur with the wider literature that reports typical sustained attention in autism. It was posited that this was due to sensory sensitivity in response to the auditory tone, which interfered with their performance accuracy. The finding that selective attention was atypical is widely supported (e.g. Burack, 1994).

Eye-tracking enabled a fourth measure of attention to be taken in the subsample analysis, this being visual attention. This measure was different in that it required minimal verbal instruction due to the fact that data were collected automatically while children were watching a video. Furthermore, it provided a measure of attention during task completion (from which the learning was assessed), which is important as all other attention measures were taken with tasks separate to the learning task, limiting the conclusions that could be drawn from any relationships between attention and learning. Contrary to existing literature, visual attention patterns did not differ significantly between the two groups, although on average autistic children did spend slightly more time looking at the background and less time looking at the teacher's face compared to TD children. The non-significant finding here was attributed to the lack of competition between social and non-social information, but it was never an aim of the study to examine this. Indeed, there was little variety in visual information to attend to, meaning that children who may have been susceptible to higher levels of visual distraction (e.g. in Hanley et al., 2017) attended to the teacher by default.

Additional to this quantitative data, observations made by teachers in Chapter Five provided real-world insights into the attentional profile of autistic pupils in the classroom setting. Teachers described the short attention span that they had observed in some pupils with autism, and as discussed in Chapter Five, this may reflect atypicalities in selective attention. Specifically, if a child with poor selective attention is distracted from their work they may be unable to reorient their attention appropriately, which presents to observers as an inability to maintain attention for longer periods of time. Teachers also described a phenomenon that in Chapter Five was conceptualised as divided attention; some children listen to the teacher despite not looking at them, and conversely, others look at the teacher but do not listen to what the teacher is saying. These observations from teachers therefore reinforced the findings in Chapter Three relating to atypicalities in selective and divided attention. That said it is important to recognise that these interpretations of the teachers' descriptions are speculative and would need to be examined in further detail, perhaps by investigating a child's attentional profile using cognitive assessments and comparing this to teachers descriptions of their attention.

Although the findings across these studies are somewhat mixed, one finding was consistent; autistic children demonstrated atypicalities in selective attention in studies across all three chapters, supporting existing literature (e.g. Renner et al., 2006). This suggests that children with autism have difficulty orienting attention appropriately, a skill that is broadly relevant to everyday life and could impact on both cognitive and social functioning. For example, in the context of a classroom, the ability to orient attention is necessary for listening to a teacher's instructions as well as looking at the relevant visual aids. Children with poor selective attention may be more susceptible to distractions if they are unable to orient their attention to an appropriate target amongst a bombardment of visual and auditory stimuli.

By comparison, the nature of executive attention in autism is still unclear, as although divided attention was found to be atypical in this thesis, executive attention in Chapter Four was not. As discussed previously, executive attention is a more complex construct than other aspects of attention, and different tasks tap executive attention in different ways. Previous studies have failed to provide a consensus with regards to the nature of executive attention in autism, which was also the case in the current thesis. That said, this thesis highlighted that executive attention ability varies depending on the demands of a particular task, with different tasks tapping different aspects of executive attention. For example, in the TEA-Ch, children must complete auditory and visual tasks simultaneously, whereas in the ANT they must make decisions based on directional cues in the presence of inconsistent distractors. Although both of these tasks aim to measure executive attention, the demands of each task are very different. This is an important methodological issue that will be discussed in more detail in the limitations section below, however in the context of the current thesis these findings demonstrate the importance of examining executive attention in more detail in autism. It is therefore vital that future research examines executive attention in autism using a variety of tasks in order to understand what aspects of executive attention performance are atypical, which will be discussed in further detail in section 7.4. The findings also highlight the heterogeneity of executive attention in autism, in that although there was a subgroup of children who performed poorly, others performed in the typical range. It may be the case that this atypicality in executive attention is more common in autism, but not unique to the disorder. This notion is reinforced by the fact that executive attention was only found to be atypical in Chapter Three but not Chapter Four. Furthermore, Posner and Petersen's (1990) multi-component theory of attention was supported, as the findings here demonstrated that children with ASD performed typically in relation to some components of attention but not others. This indicates the existence of each independent attentional process, showing that these components of attention develop independently of one another.

Importantly, these findings have provided context for interpreting other findings within the thesis. By understanding which aspects of attention are typical or atypical in autism, the relationship between attention and learning in autism can be better understood.

7.1.2 Role of attention in learning in autism

This thesis has contributed a range of novel findings to the field, particularly considering the minimal published literature on the role of attention in learning for autistic children to date. Chapters Three and Four examined the role that attention plays in learning for children with and without autism, both in terms of academic achievement (i.e. reading and maths) and during an active learning task. The studies within these chapters used a variety of methods to answer this overarching research question, allowing for a thorough examination.

In Chapter Three, it was found that divided attention was correlated with reading and maths achievement for autistic children, but not for TD children. Rather, for TD children sustained attention was related to achievement. This demonstrated that attention can play a different role in learning for different children. The relationship between divided attention and achievement in autism was investigated further, and it was found that sub-groups of autistic children, created based on divided attention task performance, had different achievement profiles. This demonstrated the specific role that divided attention plays in learning; children who performed more typically on the divided attention task had balanced profiles of reading and maths, while children who struggled with the divided attention task had within-domain discrepancies in reading and maths achievement. Specifically, their reading comprehension was significantly poorer than their basic word reading and decoding skills and their mathematical reasoning was significantly poorer than their basic numeracy. The role of divided attention in defining profiles of academic achievement was investigated further by looking transdiagnostically. This analysis demonstrated the heterogeneity in ASD, in that autistic children were represented across all three different profiles of achievement alongside TD children. Importantly, these profiles of achievement were in part defined by divided attention ability, which is a novel finding. Previously, Mayes and Calhoun (2007) found that attention was important for both maths and reading achievement, which the findings of the current thesis support, although their study used a broad measure of attention as opposed to breaking it down into its three components. In addition, May et al. (2013) found that attentional switching was concurrently important for maths but not reading, which is a finding that the current thesis supports in part. As discussed in previous chapters, however, the measures of achievement in these previous studies were not broad enough to capture the appropriate aspects of learning that attention may be important for in this group. Furthermore, represented in these studies were samples of autistic children whose IQ range was relatively small. This issue of heterogeneity will be discussed in more detail later in this chapter, however, it is important to recognise that the studies reported in the current thesis captured a wide range of children that were not represented in previous studies.

Due to the concerns regarding the divided attention task in Chapter Three, Chapter Four sought to study the relationship between attention and learning using measures requiring minimal verbal instruction. In Chapter Four, it was found that sustained attention was transdiagnostically important for lesson-based learning. Sustained attention, as measured by the ANT, was related both to increased time spent looking at the teacher during the lesson, as well as higher learning outcomes. This is a finding that supported existing literature (Hanley et al., 2017). Although this was the case for all children, some differences between TD and ASD children did exist. Specifically, autistic children who spent more time looking at the teacher's face learned more from the lesson, whereas this was not true for TD children. This was a novel finding. One possible explanation for this is that some children (e.g. those with poorer divided attention ability) need to focus both visual and auditory attention on the appropriate information during a lesson in order to learn effectively. It could be argued that this is not a well supported argument, considering the teacher comments in Chapter Five regarding the ability to listen to a teacher without looking at them. It is important to recognise, however, that teachers indicated this was not the case for all children. Indeed, one teacher described children who would be looking at the teacher but not listening. It may be that the latter children have poor divided attention ability, reflecting those who had poorer performance on the lesson based task. This notion is supported by the heterogeneity seen in divided attention in Chapter Three; although most autistic children scored at floor, there was also a sub-group of children who performed within the normal range. Together, this suggests that while autistic children with poorer divided attention may need to focus both visual and auditory attention on the teacher during a lesson, those with better divided attention may be able to process the information by only allocating their auditory attention to the teacher.

Different attentional components appeared to be at play between these studies, which may be attributable to the different measures of learning (and thus the task requirements). In Chapter Four, learning was measured using a task designed to simulate a short lesson being delivered in a classroom, and for this particular task, the ability to sustain attention was important for predicting learning outcomes. In Chapter Three, however, learning was measured using standardised assessments that aimed to capture a child's achievement in two key academic domains. These are comparable to the assessments they may complete as part of their national curriculum assessments, which are important for determining their academic pathway post-primary school. For these types of assessments, divided attention was more important. This indicates that different components of attention are important for different aspects of a child's educational experience, which is an entirely novel finding, and an important contribution to the theoretical autism literature. This also supports the multi component theory of attention (Posner & Petersen, 1990), as although attention is broadly important for learning in autism (Mayes & Calhoun, 2007), each component of attention is important for different domains of learning. As previously mentioned, the ability to divide attention between visual and auditory domains was important for performance on academic assessments of reading and maths achievement. More advanced aspects of reading and maths in particular require managing multiple demands of attention, therefore it is no surprise that divided attention ability is important for these academic domains. When reading, for example, one must pay attention not just to each individual word, but to the context of the word within sentences and paragraphs; this therefore requires attention to both local and global information simultaneously (Albrecht & O'Brien, 1993). Relating this back to the multi component theory of attention (Posner & Petersen, 1990), the notion that different components of attention are important for learning in different domains demonstrates that each attentional construct is independent, and plays its own unique role in development.

By comparison, sustained attention was found to be transdiagnostically important for paying attention to a teacher during an instruction based learning task, and for children with autism, for learning from that task. This is logical as the longer one pays attention to the learning material, the more information can be processed and subsequently remembered. If some of the information is not attended to, due to a lapse in concentration, this could not only disrupt the processing for that piece of detail, but potentially the wider context of the information. Considering that individuals with autism are known to have difficulty with processing information holistically (Frith, 1989; Happé & Booth, 2008), this may further compound any issues with learning. It is also important to recognise that divided attention may have been important for this task, but as it was not measured in the current study, this cannot be known. The measure of executive attention in Chapter Four captured an aspect of executive attention that did not tap divided attention, and was not important for learning outcomes. This reinforces the argument that executive attention in autism should be examined in more detail, in order to understand which aspects of executive attention are important for learning, and in which domains.

Selective attention was not found to be important for learning in any of the studies, which was an interesting finding considering that in this thesis it was the only aspect of attention consistently found to be atypical in autism. As discussed in detail above, different components are attention play a role in different aspects of learning. It is therefore possible that selective attention is important for an aspect of learning that was not measured in the current thesis. For example, Erickson et al. (2015) found that selective sustained attention in 5-year-old TD children predicted performance on a worksheet following a classroom-based lesson delivered by a teacher. Although Chapter Four's video lesson aimed to replicate learning within a lesson context, it was not entirely representative of classroom based learning as children were watching on a screen and any external distractions (e.g. noise and other children) were removed. Granted, the former study was conducted with TD children, but one possibility is that selective attention is more important for a holistic classroom learning experience. An alternative explanation is that selective attention may be important earlier in development for learning outcomes later in life. Steele et al. (2012) found that sustained-selective attention measured using a visual search task in 3 to 6-year-old TD children predicted basic numeracy one year later. Considering that selective attention atypicalities are present in autism from infancy (Baranek, 1999; Osterling & Dawson, 1994), it may be that selective attention plays an important role early in development for these children, impacting later learning experiences and outcomes. This is, however, speculative, and as no studies to date have considered this, future research should investigate the longitudinal impact of attention.

Despite the strength of these findings regarding the role of attention in learning, some evidence suggested that this was not a direct relationship. More specifically, in Chapter Four sustained attention and visual attention accounted for only a small amount of variance in learning. Age and IQ were generally the strongest predictors of learning, although even these alone were unable to explain much of the variance. This indicated that other factors were important, and these were investigated in Chapters Five and Six.

7.1.3 Individual differences in psychopathology/behaviour

The aims of Chapters Five and Six were to consider other factors that may influence the relationship between attention and learning. Broadly, the studies within these chapters supported existing literature in addition to presenting novel findings.

As little research on this topic exists, semi-structured interviews were conducted with teachers in Chapter Five to investigate a broad range of factors that teachers of autistic pupils identified as relevant. In Study 3a, teachers were first asked broadly about the barriers to and facilitators of learning, and identified a range of important factors. Most prominent within this discourse was the impact of aspects of the pupil, the most endorsed of these being anxiety and sensory processing. In addition, even though the focus of this section was not upon attention, teachers referred to attention as a mediating factor, for example, between anxiety and learning. This concept was strengthened in Study 3b when teachers were asked specifically about attention and the impact it has on learning. In this study, anxiety was reported as one of the most frequent distractions for autistic children in the classroom, which subsequently impacts on their ability to learn. From the findings of these studies, it was clear that the relationship between attention and learning is complex, with many factors at play. Importantly, the factors that were most prominent in the teachers' discourse and considered most specific to autism were sensory processing and anxiety. It was proposed that sensory processing difficulties and/or anxiety can cause all-encompassing distractions for these children that mean they are unable to attend to learning tasks, leading to reduced quantity or poorer quality academic outcomes. Indeed, studies have reported heightened levels of anxiety in autism (Kerns & Kendall, 2012), as well as atypical sensory processing (Ben-Sasson et al., 2009), therefore these issues raised by teachers link to known issues with the ASD literature. As the proposed theory had been developed based on qualitative data from a relatively small number of teachers, Chapter Six aimed to investigate this using quantitative methods, returning to the sample from Chapter Three.

Chapter Six considered the role of sensory processing and anxiety in the relationship between attention and learning by using parent-report measures of their child's behaviour in addition to the cognitive measures from Chapter Three. Correlational analyses found that these behavioural factors played different roles for different children. For TD children, there was an indirect relationship between divided attention and reading achievement through sensory processing. By comparison, in autism anxiety was important for divided attention and reading achievement, in that children with high levels of anxiety also had poorer divided attention, leading to poorer reading achievement. On the whole, these findings supported the theory derived in Chapter Five, although sensory processing did not seem directly important for reading achievement in autism. It was posited, however, that sensory processing difficulties may lead to heightened anxiety, which subsequently impacts on anxiety and reading achievement. Based on these findings, a novel model of the complex relationship between attention and learning in autism was proposed. Although this was based on a very small sample, it provides a clear direction for future research, which will be discussed in the appropriate section below.

Together these findings not only reinforced the notion that attention is important for learning, but demonstrated the complexity of this relationship, indicating that other factors are indeed at play. Of particular importance in autism are anxiety and sensory processing difficulties. The practical implications of this are discussed below.

7.1.4 Practical implications

As the focus of this thesis has been upon factors impacting educational outcome for pupils with autism, it is important to consider the practical implications of this piece of research. In understanding the role that attention abilities play in learning for autistic pupils, this theoretical knowledge can be applied to educational practice in order to support these children in the classroom. Furthermore, with the added contribution that anxiety and sensory processing difficulties make to this relationship, clearly there are also implications for clinical practice.

Due to the heterogeneity of the autism phenotype, including variability in attention abilities, it is highly likely that a single strategy for supporting pupils with attention atypicalities is not practical. For example, a child with poor divided attention may need different supports in place compared to a child with poor selective attention. Furthermore, as this thesis has found different components of attention to be important for different aspects of the educational experience, any attempts to improve performance in particular domains must be carefully planned. Identifying children who are struggling or at risk is therefore an important first step; based on the findings from Chapter Five, teachers appear to be good at recognising these children, particularly teachers from SEN schools. This suggests that appropriate training on how to identify attention atypicalities is warranted for teachers in mainstream schools.

Once children with these attention atypicalities have been identified, it is important to consider strategies for supporting them, tailored to their particular difficulties. In Chapter Four, it was proposed that children with poorer sustained attention may benefit from shorter learning sessions, or more frequent breaks. This suggestion was supported by the findings in Chapter Five; teachers, particularly those in schools with SEN provision, described giving children tasks with a shorter duration and breaking these up with free time. This is clearly a strategy that some teachers have already adopted in SEN schools, and may also benefit autistic pupils in mainstream schools.

Leading from this discussion regarding support for autistic children relating to their attention and learning, the findings from this thesis provide a potential basis for the design of intervention work (with the acknowledgement and caveat of basing this on relatively small sample sizes at present). Although this is an area that has received some attention in recent years (Kirk et al., 2016, 2017), the novel findings that different components of attention are important for different aspects of learning, and that anxiety and sensory processing play a role, provide a new avenue of exploration. This will be discussed in more detail in the *future directions* section below. In summary, although future research is necessary, the current findings not only have scientific implications for the theories of attention and learning in autism, but practical implications in relation to both education and clinical practice.

7.3 Strengths and limitations

So far this General Discussion has integrated the findings across chapters of the thesis, drawn conclusions, and discussed the wider theoretical and practical implications. It is also important to consider the context in which this research has been achieved, by focusing on both the strengths and limitations. Although this has already been done within each empirical chapter in relation to individual studies, the following section will discuss this in a broader sense, particularly in relation to methodology and the nature of autism research.

7.3.1 Methodology and measurement

One key strength of this thesis is that a broad range of methods have been used in order to investigate the role of attention in learning for pupils with and without ASD. Adopting this multi-methods approach allowed a detailed and thorough investigation of how attention influences learning that would not be possible within a single methodological design or using a single research technique. Using this approach across the thesis also means that the advantages and disadvantages of each individual method are more balanced. The use of standardised assessments in Chapters Three and Six allowed a large amount of control to be exercised, as these measures that have established validity and reliability. They required verbal instruction, however, restricting some participants from accessing them. Furthermore, the academic achievement measures in particular represented assessments similar to those children might complete for curriculum based assessments such as SATs, as opposed to representing learning in the context of a classroom environment. The use of a bespoke learning task in Chapter Four that simulated a teacher-delivered lesson added an aspect of ecological validity to the thesis, and using eye-tracking during this task meant that a measure of attention during a task was taken. This allowed the examination of how attention during a task can impact upon learning from that same task, which is something that standardised assessments were unable to offer. The use of a computer based measure of attention, namely the ANT, overcame issues with task difficulty that were identified in the standardised assessments. Age-appropriate scores were however not available for this task, making it more difficult to compare children against one another.

In Chapter Five, qualitative data were collected. While quantitative methods allow for high experimental control, only a small number of factors can be considered within a single study, and exploratory work would require very large samples. The data collected in experimental conditions are also restricted in that they are not entirely representative of how factors might interact in the real world. Conducting interviews with teachers both allowed for a broad range of factors to be identified, and provided rich first-hand accounts of experiences from individuals who spend the most time with autistic pupils in a learning context. These themes were then followed up with quantitative methods in Chapter Six, in which the use of parent-report questionnaire data provided scores of behaviour that would be difficult to capture experimentally (sensory experiences and anxiety). Together, this multi-method approach allowed for a detailed and rounded examination of attention in autism, and its role in learning, as well as paving the way for future research.

Although there are many strengths relating to the methodological approach within this thesis, it is also important to recognise the weaknesses. As previously mentioned, the limitations of specific studies have been discussed in the appropriate empirical chapters, however more general issues that span multiple chapters will be discussed here. The issue of task demands has been discussed previously in relation to specific studies within this thesis, but is an important issue with broad relevance. Although a range of tasks aim to measure the same abilities as one another, the demands that a particular task places on a participant can mean that performance between measures differs. For example, in Chapter Three it was found that autistic children performed typically on a sustained attention task, whereas in Chapter Four their sustained attention was identified as atypical. This may have been attributable to differences in task demands. The TEA-Ch used an auditory counting task to measure sustained attention, while the ANT required participants to determine the direction of a target, and measured sustained attention by comparing performance between trials with or without an auditory alerting cue. Although both tasks have auditory elements to them, in the latter attention was explicitly directed to the visual task, whereas in the TEA-Ch the task was entirely auditory. These tasks therefore place different demands on participants, despite attempting to measure the same construct. It may be the case that individuals with ASD are more susceptible to these differences in task demands, particularly in relation to sensory information considering that they process this differently to TD children. This issue is broadly relevant to all of the experimental tasks described in the current thesis, therefore is a limitation upon the interpretation of the findings, particularly in relation to collating findings from different studies. Importantly, as described above, this thesis has adopted multi-methods in order to thoroughly evaluate the relationship between attention and learning in autism, which includes an assessment of different components of attention using different tasks. Understanding how performance differs between these tasks and how they relate to other measures is a critical aspect of understanding attention in autism as a whole.

Another limitation of the current thesis relates to an issue raised in Chapter Five, in which it was proposed that some autistic pupils may have difficulty processing visual and auditory information simultaneously, specifically during lessons where they are required to attend to the teacher. If this is indeed the case, this has implications for methods of measuring attention in autism, particularly for eye-tracking research. One assumption underlying measures of attention obtained using eye-tracking is that patterns of visual attention reflect what an individual is using their cognitive resources to attend to (Yarbus, 1967). If some children have difficulty processing both visual and auditory stimuli simultaneously, this implies that what they are looking at during a task does not necessarily reflect what they are attending to. That said, in Chapter Four the relevant information in the video lesson was auditory, and TD children were able to remember a large amount of detail from the lesson without necessarily spending the most time looking at the teacher's face. Autistic children, however, learned more when they spent more time looking at the teacher, which suggests that it was important for them to direct both visual and auditory attention to the task in order to achieve better learning outcomes. Therefore although looking at the teacher's face supported autistic children to direct their attention appropriately, visual attention to the teacher alone was not enough in itself, as this was not important for TD children. Indeed, the outcomes measured in the learning task came solely from the auditory information. Returning to the issue in question, it is important to recognise that visual attention does not necessarily reflect a cognitive allocation of attention. Critically, this must be kept in mind when designing or selecting tasks to measure attention.

7.3.2 Heterogeneity and co-morbidity

Throughout this thesis there has been a discussion surrounding heterogeneity in autism, the importance of recognizing this in research, as well as the challenges of doing so. As this has been such a wide-reaching issue throughout, the strengths and limitations of the thesis within the context of this issue will be discussed here.

The heterogeneity of autism is receiving increasing interest, both in relation to cognition (Charman et al., 2011) and aetiology (Geschwind & Levitt, 2007). This body of research has, for the most part, focused on identifying meaningful sub-groups of autistic adults and children. By taking a novel approach to data analysis methods, this thesis has accounted for sub-groups of children with ASD who are otherwise under-represented in the literature. For example, in Chapter Three, autistic children who could not complete the divided attention task were included in an analysis by creating sub-groups of children based on ability to complete the task. Similarly, in Chapter Four, autistic children who were unable to complete the eye-tracking task were considered in comparison to those who completed it successfully.

Typically, children who are unable to do the tasks determined by researchers are excluded from studies. In reality, these are the children who deserve the most attention, particularly if the goal of research is to understand difficulties that children with autism face and devise methods of support. By including these children, and considering their performance on some tasks despite their inability to complete the full battery, this thesis has demonstrated the importance of investigating these 'non-completer' sub-groups. Had these children been excluded from the analysis entirely, certain relationships may have been missed.

Although recognising heterogeneity has been a strength of this thesis, there are also related limitations. As is relatively common in the wider autism literature, the samples in the studies reported here are small. If only small samples are used, this can lead to increased likelihood of false findings emerging (Ioannidis, 2005). Furthermore, small samples cannot accurately capture variability through random sampling, as the majority of participants recruited may perform similarly with any diversions from this being labelled as outliers; larger samples are necessary in order to capture the full range of variability, as with any individual differences research. In the current study, small samples were used, and therefore there were limitations upon data analysis and interpretation in terms of power, but this was recognised in the interpretation of findings in each chapter. As a consequence, collecting data from larger samples should be one focus of future research, which will be discussed in the *future directions* section.

Finally, an important issue to recognise is comorbidity. As well as being a heterogeneous disorder, ASD also commonly presents with comorbidities, with around 70% of autistic individuals also having at least one additional psychiatric diagnosis (Simonoff et al., 2008). Although including autistic children with additional diagnoses in research would enable a representative sample to be studied, the inclusion of children with certain comorbidities could in some cases cloud the data. In the case of the current piece of research, inclusion of children with a comorbid diagnosis of ADHD, a disorder of attention, could make it difficult, near impossible, to determine whether attention abilities of participants were related to their diagnosis of ASD or ADHD. Simonoff et al. (2008) found that of 10 to 14 year olds with ASD, 28.2% also had an ADHD diagnosis, and further research has found that up to 50% of school-age individuals with ASD manifest ADHD symptoms (Davis & Kollins, 2012). Although in the current research programme children with a comorbid diagnosis of ADHD were excluded (as confirmed by parental report), there is a possibility that some children had clinically heightened ADHD symptoms and possibly undiagnosed ADHD, particularly since it was not possible to receive a comorbid diagnosis until the publication of DSM-5 six years ago (APA, 2013). In Chapter Four, parents were asked to complete the Conners Parent Rating

Scale 3-Short Form (Conners, 1997), which aimed to control for prevalence of undiagnosed ADHD. Unfortunately, the return rate for this questionnaire was poor, therefore it was not possible to include this data in the study. It therefore remains a possibility that some individuals with ASD in the reported samples had heightened ADHD symptoms that may have impacted on the findings. As one of the main aims of the current thesis was to investigate the attention abilities of a heterogeneous sample of children with ASD, the inclusion of children with heightened ADHD symptoms may not be problematic, as the sample should be representative of the ASD population. That said, this raises an important issue for future research, which should consider this possible subgroup of individuals in further investigations of attention in ASD.

Within this issue of co-morbidity, it is also important to acknowledge that the samples reported within this thesis do differ somewhat between chapters. As previously mentioned, in the quantitative studies of this thesis (Chapters Three, Four and Six), autistic children without co-morbid ADHD were recruited. The samples within these studies therefore represent a sub-set of the ASD population. By comparison, in Chapter Five when engaging in the interviews teachers were asked to think about pupils with ASD broadly. As a consequence, the sample described by teachers within this study likely represented a heterogeneous group of autistic pupils (who may have had co-morbidities). This has implications for drawing together the findings of the quantitative and qualitative chapters of the current thesis, and must be taken into account when interpreting the findings. As discussed above, this issue of co-morbidity is an important one within ASD research generally, with ways to address this issue still under debate.

7.4 Future directions

As the current thesis has shown that attention abilities are important for learning, one direction for future research, as alluded to above, would be the development of attention training based interventions for autistic pupils with poorer attention. The aim of such programmes of training would be to improve specific attention abilities and as a consequence, improve learning outcomes. This is an area of research currently being developed, for example, by Kirk and colleagues (see Kirk et al., 2016, 2017). These studies were aimed at improving attention for children with intellectual and developmental disabilities (IDD) more broadly, but included children with autism. In their initial study, Kirk et al. (2016) report a computer based intervention using tasks to improve the different components of attention, these being: visual search task (selective attention), vigilance task (sustained attention), conflict resolution task and response inhibition task (executive attention). They found that the intervention was successful in improving selective attention for children with IDD, but when examining whether these improvements transferred to domains of learning (i.e. reading and maths), there were no immediate gains, and only small gains in maths after 3 months (Kirk, et al., 2017). The authors argue that it may take 6 to 12 months for the benefits of the training to be apparent, however based on the findings of the current thesis, this could be attributed to the fact that selective attention is not necessarily important for reading or maths achievement. Furthermore, their study included children with IDD more broadly, whereas the relationship between attention and learning in autism may be different (e.g. syndrome-specific in nature). For example, anxiety and sensory processing also play a role and should be taken into account when considering the 'whole' child and their abilities and disabilities. Interventions for autistic children should therefore be tailored based on the unique ways in which aspects of behaviour and cognition interact and impact upon learning. For example, children with poorer maths achievement may require training in divided attention, while those who struggle with instruction based learning tasks could benefit from sustained attention training. In addition, strategies for coping with anxiety and/or sensory processing difficulties would need to be built into the interventions. Before any intervention studies can begin, however, it is clear that more research is needed to understand the underlying relationships further.

As the relationship between attention and learning is clearly complex, particularly considering the findings that anxiety and sensory processing may also play a role, rigorous experimental research should examine this further. Specifically, the model proposed in Chapter Six should be tested with broader and more varied measures of behaviour, attention and learning. As each attentional component plays a different role for different aspects of learning, it is entirely possible that this is also the case for aspects of behaviour. Future research should therefore measure learning not only using assessments of specific academic domains, but other tasks relevant for classroom based learning, such as instruction-based tasks. Furthermore, due to the limitations of report-based measures of behaviour, multiple respondent reports should be taken to gain a rounded behavioural profile of the child (i.e. teacher, parent and self-report). To further enhance the quality of our understanding of these behaviours and their impact on attention and learning, direct measures should be used. For example, some studies have measured anxiety and sensory processing difficulties in children with autism using physiological methods (Kushki et al., 2013; Levine et al., 2012; Shaaf et al., 2010). In addition to using a variety of methods to test this model, a large and heterogeneous sample is also necessary, including a TD comparison group. The study reported in Chapter Six was a preliminary examination of the proposed relationships from Chapter Five, but requires a large sample to test the model rigorously.

Another important focus for future research should be upon understanding executive attention in autism, which is an issue that has been touched upon many times in the current chapter. Executive attention performance varies between tasks, suggesting that this variability is due to the differences in task demands. For example, tasks designed to tap executive attention but require aspects of orienting attention (e.g. visual search) may lead to poorer executive attention performance. Equally, it may be that autistic children struggle with dividing or shifting attention due to difficulties with mental flexibility, but are able to complete executive attention tasks based around conflict resolution due to their strength in local over global processing (Happé & Frith, 2006). Steele et al. (2012) refer to the importance of understanding the trajectories of performance on different executive attention tasks in TD children, and this is also true in autism. Executive attention is clearly complex and relies on other cognitive functions, but understanding how autistic children perform across this range of tasks could advance theoretical models of attention in autism. Related to this, an important future direction for this work would be to take a developmental approach and examine the trajectories of attention in ASD. Understanding how these attentional mechanisms change over time, and how this impacts on learning at different ages, would provide even more evidence to support the advancement of theoretical models.

7.5 Conclusions

This thesis has provided a significant contribution to our understanding of attention in ASD, and how it impacts on learning for autistic pupils. The multi-methods approach adopted within this thesis has allowed for a broad and rich investigation of this relationship. Supporting existing literature, selective attention was consistently found to be atypical in children with autism. The variability of executive attention performance in autism was also supported, which led to the conclusion that a more thorough investigation of executive attention in autism is vital. Using a variety of methods, this thesis demonstrated the importance of attention in learning for autistic pupils, showing that different components of attention play a role in different aspects of learning. Furthermore, exploratory analyses highlighted the complexity of the relationship between attention and learning, in that anxiety and sensory processing also play a vital role. Taken together, the thesis has therefore provided a comprehensive and valuable insight into the role of attention in learning for autistic pupils, offering clear directions for future research.

Appendices

Appendix A: Chapter Four worksheets and scoring examples

<u>Lesson 1: The Salmon of Knowledge</u>

Section A: Sentence match questions

1. When Fionn’s father was killed in battle, his mother sent him:

    a. To be raised by two wise women who lived in the woods.

    b. To live with his uncle in a village near the river Boyne.

    c. To school.

2. In order to become the leader of the army, Fionn as a young boy was taught:

    a. To protect himself with a shield and a sword.

    b. How to use a knife and fork.

    c. How to use a bow and arrow.

3. When Fionn brought Finnegus the fish, Finnegus looked into his eyes and knew immediately:

    a. That Fionn had eaten most of the fish already.

    b. That Fionn had received the gift of knowledge.

    c. That Fionn was feeling sick.

4. Fionn was:

    a. Brave and good at many sports.

    b. Clever and good at writing poetry.

    c. Handsome and kind.

Section B: Recognition

1. What is the biggest army in Ireland called?

    a. The Farriers

    b. The Fianna

    c. The Fionns

2. How many books of poetry did Fionn need to learn by heart?

    a. Twenty books

    b. Twelve books

    c. Seven books

3. The salmon of knowledge was

a. shiny and grey

b. beautiful and shone like gold

c. beautiful and shone like silver

4. What did Fionn do when he burnt his finger on the fish while cooking it?

a. He put his thumb in his mouth to try and ease the pain

b. He screamed in pain and began to cry

c. He put his thumb in cold water to ease the pain

Section C: Comprehension

1. Was the salmon of knowledge easy to catch? Why?

No (1)

No, because it was rare / because it took a long time to catch (2)

2. Why couldn't Finnegus and Fionn just share the 'Salmon of Knowledge', and both get the gift of knowledge?

Because only one person can get it (1)

Because the first person to taste it gets the gift of knowledge (2)

3. How do you think Finnegus felt when he found out that Fionn has tasted the Salmon of Knowledge?

Upset / sad / disappointed (1)

Upset / sad / disappointed but he forgave Fionn (2)

4. Did Fionn mean to take the gift of knowledge for himself?

No (1)

No, it was an accident (2)

5. Why do you think Fionn would be a good leader of the Fianna?

He was: wise, brave, could use a shield and a sword, had the gift of knowledge, could tell the future (the child needs to provide 2 of these to get 2 points, or 1 for 1 point.)

<u>Lesson 2: Oisin in the Land of Youth</u>

Section A: Sentence match questions

1. When Oisin and his father were hunting they saw:

a. A woman on a snow-white horse.

b. A woman on a snow-white deer.

c. A deer hiding behind a tree.

2. Oisin and Niamh lived happily in the Land of Youth for almost three hundred years, although:

a. It rained a lot.

b. It felt like an eternity since he left home.

c. It felt no longer than a few days to Oisin.

3. When Oisin returned to Ireland he found that everything:

a. Was just as he remembered.

b. Was now in ruins.

c. Was painted green.

4. When Oisin found no trace of his friends and family:

a. He decided to keep searching for them.

b. He decided to go on holiday.

c. He decided to return to the land of youth.

Section B: Recognition

1. What were Fionn and his son Oisin doing in the valley near the lakes of Killarney?

a. Hunting with the Fianna

b. Hunting on their own

c. Getting some exercise

2. Why did the beautiful princess ask Oisin to come with her to the 'land of youth'?

a. Because she really liked him and wanted a friend in the land of youth

b. Because she had fallen in love with him and wanted to be his wife in the land of youth

c. Because she wanted him to catch deer for her in the land of youth

3. What was the promise that Oisin made to Niamh before going back to visit Ireland from the land of youth?

a. That he would never get off the white horse

b. That he wouldn't let anyone else on the white horse

c. That he would not be long, because she would miss him

4. Why did Oisin get off the horse, even though he had promised Niamh that he wouldn't?

a. Because he thought that nothing would happen and Niamh was just joking

b. Because he had forgotten about their promise and wanted to help some men lift a heavy rock in a field *c. He didn't mean to break his promise, it was an accident*

Section C: Comprehension

1. What would have made Oisin happier in the Land of Youth?

To see his father / friends / family or have them with him (1)

To see his father AND friends / Fianna again / one more time (2)

2. How do you think Oisin felt when he was on his way back to Ireland from the Land of Youth?

Sad (to leave Niamh), excited / happy (to see his father & friends) –1 point for one of these, 2 points for both

3. Why do you think Oisin couldn't find his father and friends when he came home after living in the Land of Youth?

They were dead (1)

It had been 300 years so they would have all died (2)

4. Why did Oisin decide to help the men on his return?

They were struggling to lift the rock OR he was strong / could lift the rock (1)

The men were struggling and he was strong so knew he could lift the rock (2)

5. Do you think it was a good idea for Oisin to come back to Ireland on the snow white horse?

No (1)

No, because he died (2)

Lesson 3: Setanta

Section A: Sentence match questions

1. Culann owned a large fort because:

a. He wished for it and his wish came true.

b. He earned lots of money from making swords, spears and shields.

c. His parents gave it to him.

2. Culann protected his fort using:

a. A scarecrow.

b. A guard with a sword.

c. A savage hound.

3. When the dog first saw Setanta he jumped over the gate and:

a. Barked and licked him on his face.

b. Barked and showed his fierce sharp teeth.

c. Chased a cat.

4. The Macra was the name of:

a. A group of young warriors.

b. Cullan’s fort.

c. The guard dog.

Section B: Recognition

1. What was the name of the king of Ulster at the time of this story?

a. Culann

b. Setanta

c. Conor

2. How is Setanta related to the king of Ulster?

a. The king is his brother

b. The king is his father

c. The king is his uncle

3. What did Culann do for a living?

a. Culann is a Blacksmith

b. Culann is leader of the Macra

c. Culann is a swordsman

4. How did Setanta come to be known as ‘Cuchulainn’

a. He did not like the name Setanta

b. Because he became responsible for guarding Cullann’s fort

c. Because he was a great warrior

Section C: Comprehension

1. Why was Setanta late for the feast?

He was playing (1)

He was playing a game of hurling and wanted to finish it first (2)

2. Why did Conor let Cullann release his guard dog even though Setanta was still outside?

He forgot (1)

Conor had forgotten that Setanta was coming to the feast / had not arrived (2)

3. How did Setanta feel when he first saw the guard dog behind the gate?

Brave / not scared (1)

He wasn't scared because the dog was behind the gate (2)

4. When Setanta threw the ball at the dog, how do you think he was feeling?

Sad that he had killed the dog (0)

Upset (1)

Scared / worried (2)

5. Why did Setanta offer to guard the fort for Cullan?

He killed the dog (1)

Because he was responsible for killing the guard dog and offered to guard it until Cullan found a new guard (2)

Appendix B: Chapter Four question validation data

Table B.1. Chi-square values for Lesson 1 question validation.

Question	*1-A1*	*1-A2*	*1-A3*	*1-A4*	*1-B1*	*1-B2*	*1-B3*	*1-B4*	*1-C1*	*1-C2*	*1-C3*	*1-C4*	*1-C5*
X^2	0.14	5.14	0.14	0.57	0.14	0.57	-7	2.22	1.28	-7	0	3.57	0.57

Table B.2. Chi-square values for Lesson 2 question validation.

Question	*2-A1*	*2-A2*	*2-A3*	*2-A4*	*2-B1*	*2-B2*	*2-B3*	*2-B4*	*2-C1*	*2-C2*	*2-C3*	*2-C4*	*2-C5*
X^2	0.57	0.14	1.28	0	0	5.14	0.14	5.14	0.57	0.14	-3.57	-0.14	0.57

Table B.3. Chi-square values for Lesson 3 question validation.

Question	*3-A1*	*3-A2*	*3-A3*	*3-A4*	*3-B1*	*3-B2*	*3-B3*	*3-B4*	*3-C1*	*3-C2*	*3-C3*	*3-C4*	*3-C5*
X^2	5.14	0.57	1.28	0	-0.57	0.57	-1.28	-0.57	-7	-7	0.57	-7	-3.57

Values below the $p < .05$ cut-off value of 5.99 were considered acceptable questions. Any questions scoring above 5.99 were not included in the final worksheet. Data are from 6 to 11-year-olds (N = 20) who had not seen the video lessons.

Appendix C: Chapter Four correlation tables for Lessons 1 and 3 data only

Table C.1. Correlation matrix for full sample, including only data from Lesson 1 and 3 (N = 48)

	1	2	3	4	5	6	7	8
1. Age								
2. FSIQ	-0.72							
3. Learning outcome	.228	.703***						
4. Alerting RT	.003	.144	.217					
5. Orienting RT	.03	.171	.009	-.264*				
6. Executive RT	-.147	.230	.237	.249*	.177			
7. Alerting % errors	-.025	-.04	-.053	-.107	.283*	.02		
8. Orienting % errors	.185	-.171	.028	.081	.033	-.084	.075	
9. Executive % errors	-.295*	.006	-.187	-.038	.207	.277*	.255*	-.160

All correlations are one-tailed, *p <.05, ** p <.01, *** p < .001

Appendix D: Chapter Four full sample correlational data by group

Table D.1. Correlation matrix for full sample TD group (N = 27)

	1	2	3	4	5	6	7	8
1. Age								
2. FSIQ	.102							
3. Learning outcome	.410*	.590**						
4. Alerting RT	.391*	.01	.307					
5. Orienting RT	-.09	.005	-.249	-.295				
6. Executive RT	.303	.172	.267	.341*	-.156			
7. Alerting % errors	-.275	-.056	-.358*	-.160	.215	-.235		
8. Orienting % errors	.202	-.1	-.102	.185	.307	.115	.025	
9. Executive % errors	-.134	-.153	-.279	-.171	.127	.003	.478**	.084

All correlations are one-tailed, *p <.05, ** p <.01, *** p < .001

Table D.2. Correlation matrix for full sample ASD group (N = 21)

	1	2	3	4	5	6	7	8
1. Age								
2. FSIQ	-.093							
3. Learning outcome	.271	.770***						
4. Alerting RT	-.3	.264	.157					
5. Orienting RT	.116	.289	.238	-.23				
6. Executive RT	-.467*	.279	.079	.109	.479*			
7. Alerting % errors	.378*	-.114	.131	-.065	.389*	.228		
8. Orienting % errors	.226	-.24	.165	-.052	-.26	-.382*	.113	
9. Executive % errors	-.453*	.116	-.154	.124	.289	.661***	.067	-.426*

All correlations are one-tailed, *p <.05, ** p <.01, *** p < .001

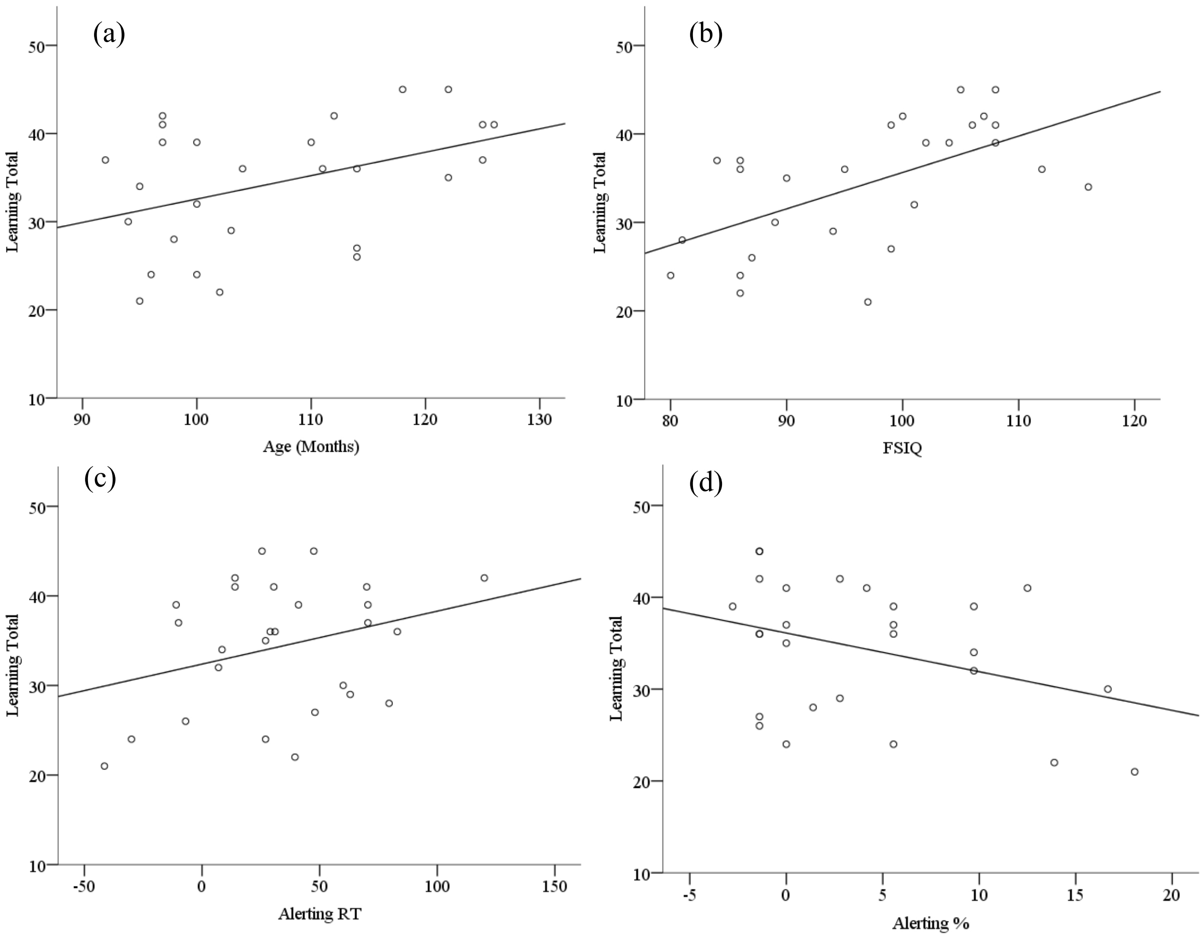


Figure D.1. Scatterplots for Study 2a TD sample (N = 27) for correlations between (a) learning and age, (b) learning and IQ, (c) learning and alerting RT, and (d) learning and alerting accuracy.

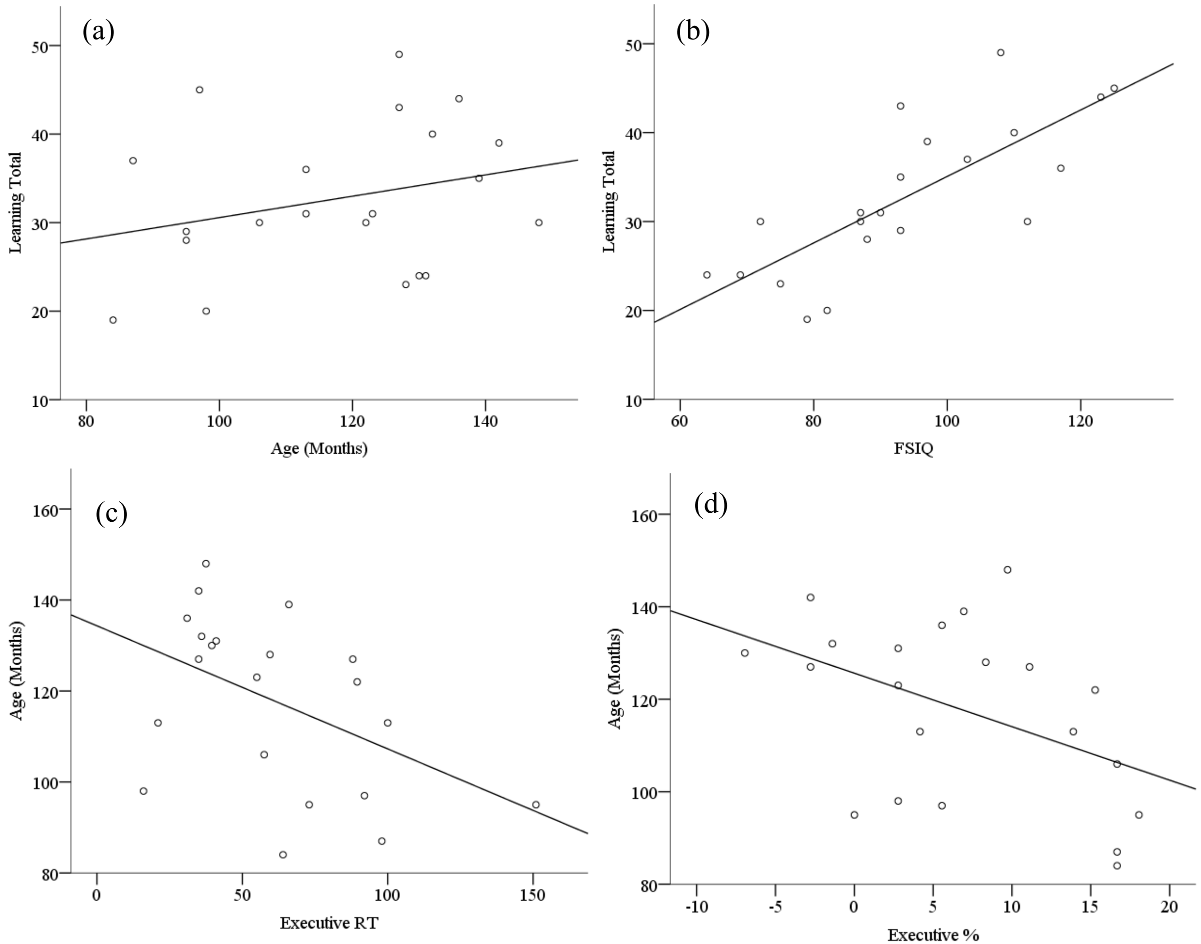


Figure D.2. Scatterplots for Study 2a ASD sample (N = 12) for correlations between (a) learning and age, (b) learning and IQ, (c) age and executive RT, and (d) age and executive accuracy.

Appendix E: Chapter Four subsample correlation data by group

Table E.1. Correlation matrix for subsample TD group (N = 22)

	1	2	3	4	5	6	7	8	9	10
1. Age										
2. FSIQ	.151									
3. Learning outcome	.561**	.604***								
4. Alerting RT	.417*	-.032	.326							
5. Orienting RT	-.071	-.011	-.382*	-.268						
6. Executive RT	.316	.192	.349	.36*	-.106					
7. Alerting % errors	.27	.033	.491**	.218	-.219	.201				
8. Orienting % errors	.262	-.176	-.206	.16	.372*	.14	.014			
9. Executive % errors	.09	.074	.381*	.184	-.116	-.026	.448*	-.086		
10. Teacher's face looking time (%)	.474*	.023	.225	.26	-.18	-.121	.271	.17	.212	
11. Background looking time (%)	-.496**	-.056	-.262	-.224	.189	.118	-.28	-.141	-.212	-.986***

All correlations are one-tailed, *p <.05, ** p <.01, *** p < .001.

Table E.2. Correlation matrix for subsample ASD group (N = 12)

	1	2	3	4	5	6	7	8	9	10
1. Age										
2. FSIQ	-.376									
3. Learning outcome	-.102	.766**								
4. Alerting RT	-.277	.372	.422							
5. Orienting RT	-.035	.395	.158	.08						
6. Executive RT	-.772**	.263	-.053	.225	.417					
7. Alerting % errors	-.35	.221	.069	.038	-.021	.036				
8. Orienting % errors	.343	-.132	.305	-.028	-.178	-.484	-.319			
9. Executive % errors	.639*	-.203	.132	.11	-.447	-.874***	-.168	.326		
10. Teacher's face looking time (%)	-.311	.519*	.672**	.312	.074	.161	.21	.446	-.185	
11. Background looking time (%)	.302	-.212	-.435	-.454	.331	-.073	-.179	-.399	0	-.845**

All correlations are one-tailed, *p <.05, ** p <.01, *** p < .001.

Appendix F: Chapter Five interview schedule

QUALITATIVE INTERVIEW INTRODUCTION

Length: 45-60 minutes

Primary goal: In this interview, we will cover some basic information about your teaching background and experience, before discussing your views on the barriers and facilitators to learning in the classroom for children with autism.

Ethical reminders: Before we start I would like to remind you that you have the option of omitting any questions that you do not want to answer. I would also like to remind you that the interview will be audio-recorded for transcription, and that it will be kept on an encrypted hard drive accessible only to the researcher. The transcript will remain completely anonymous, in that it will contain no personal data.

Are you happy to continue? Do you have any questions before we start?

SECTION ONE: BACKGROUND

1. Can you tell me a little bit about your teaching experience – for example how long have you been teaching and do you currently teach in mainstream school or a school for children with special educational needs?
    a. Probe age range
    b. Probe both current and previous experience

2. Thinking back to your teacher training, did you have any training on working with pupils who have additional needs, and if so did Autism feature in that training at all?
    a. Probe when training was completed, and if received autism training, probe how much
    b. Probe knowledge of autism before teaching

3. How long have you been teaching / supporting a pupil with autism, and approximately how many children with autism do you currently work with?
    a. Probe how many children with autism previously worked with

4. Can you tell me a little bit about the current classroom environment you teach in, for example, how many pupils are in a classroom, and how pupils with autism are supported within this environment?
    a. Probe whether the children with autism spend any time out of class / receive 1 to 1 support.

SECTION TWO: FACILITATORS AND BARRIERS TO LEARNING

I'd now like to move on to talk about potential barriers to learning in the classroom. When I talk about learning, I am referring to academic outcome.

1. Thinking about children with autism, can you tell me a little bit about the most important factor that you feel negatively affects a child's ability to learn in the classroom?
    a. Probe whether this the same for TD and ASD
    b. Probe whether this is the same for all children with ASD
    c. Probe whether this is the same for different age groups (ASD)
    d. Probe specific examples of this

2. Thinking about children with autism, can you tell me what you think might be the second and third most important factors that you feel negatively affect a child's ability to learn in the classroom?

I'd now like to move on to talk about potential factors that facilitate learning in the classroom.

3. Thinking about children with autism, can you tell me a little bit about the most important factor for supporting a child's ability to learn in the classroom?
    a. Probe whether this is the same for TD and ASD
    b. Probe whether this is the same for all children with ASD
    c. Probe whether this is the same for different age groups (ASD)
    d. Probe specific examples of this

4. Thinking about children with autism, can you tell me what you think might be the second and third most important factors for supporting a child's ability to learn in the classroom?

5. Is there anything else you would like to mention in relation to facilitators and barriers to learning in the classroom? We want to know as much as possible.

SECTION THREE: ATTENTION AND LEARNING IN THE CLASSROOM

I'd now like to talk to you more specifically about attention skills in relation to learning in the classroom for children with autism. When I talk about attention skills, I am referring to a child's ability to sustain, maintain or control their attention while they are in the classroom.

1. Thinking specifically about pupils' attention skills, can you tell me a little bit about whether or not you think they are relevant for learning in the classroom? (And why?)
    a. Probe whether this is the same for TD and ASD.

2. If any exist, what kinds of elements do you feel are most distracting for children when they are in the classroom?
    a. Probe whether this is the same for TD and ASD.
    b. What sort of impact do you think this has on their learning, if any?
    c. What sort of impact do you think this has on their behaviour in the classroom, if any?
    d. Probe specific examples

3. Is there anything else you would like to mention in relation to attention skills and learning in the classroom? We want to know as much as possible.

Thank you for taking the time to answer my questions. If you have any questions, I will try to answer them for you.

END OF INTERVIEW

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